# INTEGRATED BALLISTIC DATA SYSTEM
# STATEMENT OF WORK
W9124R05T0038 CLIN 0002

1. **INTRODUCTION** Yuma Test Center (YTC) performs various ballistic and chronographic measurements of military weapons and munitions. Engineering measurements include time histories of transient internal pressures, projectile velocities, key ballistic event times, recoil displacements, structural strains, pyroshock accelerations, nearby noise and blast pressure impulses, and other characteristics represented by transducer signals. YTC tests in open-air desert range conditions. Transducers are typically located in and on weapon tubes and chassis or within 100 meters of the weapon. Pre-fire and firing signals are provided to allow sequencing and synchronization of other systems. Networked chronography units may also be many kilometers downrange near the target area to measure time of flight. Firing intervals vary between a few seconds to several minutes depending on data requirements and test design. Weapon fire controls may significantly re-aim a weapon for controlled burst firings. This requires computer control of positioners to align transducers or instruments with weapon geometry changes. YTC operates three different types of ballistic data systems, four different types of Doppler velocimeters, and assorted timing equipment and software applications with different capabilities from various sources. Setup, calibration, operation, and data processing procedures vary by system. Older subsystem parts are failing and have no OEM support. Recurring security mandates force operating system changes, which require system computer and application software updates. Data delivery from these systems is increasingly at risk because of age, operating system upgrades, fewer personnel for maintenance, and to provide training and proficiency certification for numerous systems with similar functions.

2. **OBJECTIVES**

2.1. **General.** Each new ballistic system is intended to:

a. Improve productivity to increase mission tempo with current workforce.
b. Increase performance and confidence in measurements and data products.
c. Improve maintainability and up-time.
d. Avoid or reduce impacts of operating system updates.
e. Improve software maintenance and ease future upgrades with proper software engineering and self-documentation practices within source code and associated files.
f. Reduce physical space requirements in truck shelters, vans, and fixed firing facilities.

2.2. **Capabilities.** YTC intends to replace its ballistic data systems with a single system which integrates new commercially available hardware and certain Government furnished equipment (GFE) with a new software application to provide:

a. Electronic data acquisition.
b. Calibration and field verification checks.
c. Doppler radar velocimeter control.
d. Sequencing.
e. Ballistic chronography.
f. Pan/tilt positioner control.
g. Data management and manipulation.

2.3. **Configuration.** YTC desires the system scaled to three capability configurations. One software application shall be used for all configurations. The nominal configuration objectives are 8, 32, and 128-channel systems. Channels will produce data from at least charge (PE), strain and pyroshock/acceleration (resistive bridge), constant current (IEPE/ICP), and voltage mode transducers and instruments. In addition, YTC desires continued use of specific new equipment that is currently fielded unless there is a strong rationale to abandon it.

3. **SCOPE** You shall deliver complete and operational systems. System design approach and details are considered flexible within system objectives and requirements. A first key milestone shall

initially demonstrate and certify software expectation to fully succeed using the GFE. A functional flowchart or outline indicating design approach and features. Additional interim reviews shall be proposed and executed, as you consider necessary. With the exception of individual COTS items, the entire system shall be non-proprietary. Rights to use any or all parts of the system concept, design, production, and software shall be open and unrestricted for the Contractor and Government. Any significant variance from the basic requirements shall have a compelling rationale. Overall quantities and expected hardware and software are presented as follows:

3.1. **Configuration & Quantity Profile.** On average, each system is expected to be outfitted with modules to provide about one-half of its full capacity. All hardware and software shall be common for all systems with the exceptions of rack quantity and mainframe size. YTC mission priorities will likely require acquisition of basic and intermediate systems before the large systems. The following list reflects the approximate planned system quantities. These are likely to vary based on mission and budget.

| | |
|---|---|
| a. Basic Systems, approximately 8 channels | 9 |
| b. Intermediate Systems, approximately 32 channels | 8 |
| c. Large Systems, approximately 128 channels | 3 |

3.2. **Hardware.** YTC anticipates each system will require and integrate some or all of the following component types.

a. Analog signal conditioning modules and controller/mainframe (YTC preference below).
b. Digitizers and controller/mainframe to convert analog signals to buffered digital data.
c. Calibration instruments to allow comprehensive self-calibration traceable to NIST and provide rapid pre- and post-mission system health verification reports.
d. Doppler velocimeter radar analyzers. (GFE, Weibel W-700 with RemDopp and Infinition JB-5000 with TestCenter).
e. Sequencer/timing event controller and relays to provide TTL outputs and contact closures at precisely programmed pre-fire, fire, and post-fire times.
f. Time source and measurement unit and ballistic chronograph (GFE).
g. Instrument pan/tilt positioners (for approximately one fourth of all systems).
h. System control computer and large dual monitors.
i. Other hardware including rack(s), cables, patch/interface panels, etc.

3.3. **Software Application.** A single application is required for a technician to efficiently calibrate, setup, and operate the system over a range of firing rates. The system shall provide sequencing outputs, automatically control positioners, and manage, analyze, and display data products. The system shall provide ballistic chronography and be upgradeable in the future to participate with a separately developed, dedicated ballistic chronograph. The system software shall take direct control of a Doppler velocimeter analyzer or at least work concurrently with velocimeter software without degradation or interference to any application when performing all functions and collecting data from a limited number of channels. Major software functions and characteristics shall include:

a. Startup initialization and self checks.
b. Setup.
c. Data acquisition.
d. Utilities such as supervisory controls, full calibration, and rapid system verification/health reporting for all electronic data channels.
e. Doppler velocimeter control and concurrent operation.
f. Precise sequencing of output trigger pulses and contact closures.
g. Ballistic chronography of up to six (6) events and durations between the events.
h. Positioner (pan/tilt) control.
i. Data management including formatting, local recording and filing, and remote archival.
j. Basic data manipulation, display, and conversion (quick look display to verify acquisition, data analysis display with data utilities, inter/intra-channel math, save derived data and export to other format including ASCII).
k. Design and structure to take advantage of unused hardware features and expand capabilities in future upgrades. Examples of future options include: Activation of TEDS features, advanced data analysis, display, conversion (differential, integral,

FFT, filtering, smoothing, GFI noise and blast overpressure algorithms, shock response spectrum, power spectral density, etc.), and control of additional positioners, velocimeters, chronographs and other types of equipment.

l. User interface that is intuitive, maximizes system control and flexibility, controls screen clutter, allows fast and effective train-up, and contains help for hardware and suggested control settings.

m. Coding language(s) shall be the most recent release(s) of common, industry-standard programming tools. Examples include Visual C, Visual Basic, LabView, or equals. You shall provide your own copy(s) of any coding language(s) and toolsets necessary for software development.

n. Source code shall be designed and documented to the best commercial standards including fault detection and tolerance to insure stable execution of all system functions.

3.4. **Documentation.** At least the following documentation is required.

a. Major new OEM hardware component manuals with parts lists and schematics.
b. Complete system diagrams, user setup, operation, and troubleshooting manual.
c. Users' quick reference guide.
d. Embedded documentation within source code and associated files and data.
e. All final install and software source code and associated files and data.

3.5. **Training.** You shall provide train-the-trainer instruction for up to four (4) senior technical personnel. Training shall consist of at least high to mid-level system design and behaviors, and detailed procedures for setup, calibration, checkout, operation, troubleshooting, and shutdown.

## 4. PERFORMANCE REQUIREMENTS

4.1 **Overall.** Performance requirements are based on transducer measurements which include the following types.

| | | |
|---|---|---|
| a. | Interior Ballistics - Piezoelectric (charge mode) pressure gages* | 150,000 PSI |
| b. | Interior Ballistics - Piezo-resistive pressure gages | 5,000 PSI |
| c. | Blast Over-Pressure – ICP/IEPE (constant current) pressure gages | 200 PSI |
| c. | Ballistic Shock – Piezo-resistive accelerometers | +/-200,000 g |
| d. | Strain - Axial and rosette (T, rectangular, delta) strain gages | +/-150,000 uE |
| e. | Noise / Acoustics - B&K Microphones w/Nexus Amplifier | +/-1 PSI |
| f. | Displacement – TempoSonics Transducer | +/-100 Inches (+/- 10 V output) |
| g. | Timing Signals – Various IR detectors & microwave triggers | various voltages |

* sensitivity range approximately 0.2 to 2.0 pC/PSI

4.2. **Signal Conditioning.** Provide high channel density analog signal conditioning. Although not an absolute requirement, YTC desires delivery of particular models of signal conditioning equipment unless a strong rationale is provided to reject it. These consist of Precision Filters Inc. 28000 series cards and mainframes. YTC recently selected and started fielding these assets and desires to standardize use of this equipment because of its features and performance. In addition, this will avoid premature replacement and reduce inventory requirements by sharing hardware between existing and new systems. This is considered in the best interest of the Government. It provides good performance, allows expansion to 256 channels, avoids unnecessary costs, and starts solving operational, software, and training problems associated with multiple types of similar hardware. Key performance characteristics are outlined below for the major signal conditioning components. These requirements shall be equaled or exceeded by any proposed substitute.

4.2.1. <u>Channels</u> Each channel shall have at least the following characteristics. Note: The preferred channel types are combined on two card models. These are a dual-mode four-channel charge/IEPE card (28334) and a four-channel bridge/voltage card (28104).

4.2.1.1. Charge.

a. Minimum 2 Input Ranges(software select/read): +/-50,000 pC
+/-500,000 pC
b. Input Impedance: >10^13 Ohm
c. Input Type (software select/read): isolated or grounded return
d. Time Constants (software select/read): 10 to 50,000 s
e. Charge Conversion Accuracy <+/-0.1 %
f. Noise, maximum: <0.5 pC
g. Drift, maximum: <2 pC/s
h. Charge Reset (software select /read): automatic or manual discharge
i Filter & Cutoffs (software select/read): 6 pole Bessel, at least 20 frequency cutoffs of 1, 2, 4, 5, 10, 20, 40, .... to 200,000Hz
j. Filter bypass (software select/read)
k. Frequency Response (filtered): 1 to 200,000 Hz
l. Frequency Response (filter bypassed): 1 to 500,000 Hz
m. Linearity: <+/-0.01 %
n. Gain/Scaling (software select/read): at least 40 steps such as 1, 1.25, 1.5, 2, 2.5, 3, 4, 5, 6, 8, 10, 12.5, 15, .... to 10,000x
o. Output: <+/-10 Volt
p. Calibration, Performance and Health: Software select/read. Onboard automatic offset zeroing, shunt calibration, shorted noise, offset, overload, and other fault detection. Test inputs for channel calibration and performance verification signals.
q. Identification (software read): Onboard information available including but not limited to model, serial number, firmware version, and installed options.

4.2.1.2. IEPE.

a. Current Supply (software select/read): 0 to 20 mA, in 1 mA steps
b. Input Type (software select/read): isolated or grounded return
c. Current Uncertainty, Maximum: <+/-0.1 mA
d. Voltage (DC bias + signal): 0 to 22 V
e. Filter & Cutoffs (software select/read): 6 pole Bessel, at least 20 frequency cutoffs of 1, 2, 4, 5, 10, 20, 40, .... to 200,000Hz
f. Filter bypass (software select/read)
g. Frequency Response (filtered): 1 to 200,000 Hz
h. Frequency Response (filter bypassed): 1 to 500,000 Hz
i. Gain/Scaling (software select/read): at least 40 steps such as 1, 1.25, 1.5, 2, 2.5, 3, 4, 5, 6, 8, 10, 12.5, 15, .... to 10,000x
j. Output: +/-10 Volt
k. Linearity: <+/-0.01 %
l. Output Uncertainty, Maximum: <+/-0.1 %
m. Thermal Drift, Maximum: <+/-0.003 mV/degC
n. Calibration, Performance and Health: Software select/read. TEDS ready. Onboard automatic offset zeroing, DC bias monitoring with lower/upper threshold limit alarms, shunt calibration, shorted and zero excitation noise levels, AC response, offset, overload, and other fault detection. External source test inputs for channel calibration and performance verification signals.
o. Identification (software read): Onboard information available including but not limited to model, serial number, firmware version, and installed options.

4.2.1.3. Bridge and Voltage.

a. Excitation Level (software select/read): 0 to 20 V, in 5mV steps
b. Excitation Sense (software select/read): Provide sense line for excitation voltage.
c. Excitation Sense Current: <10 microAmp
d. Excitation Voltage Regulation: <+/-0.03 %
e. Excitation Noise: <100 microVolt rms

f. Excitation Thermal Drift: <+/-0.0025 %/degree C
g. Bridge Type with Read Back: 350 Ohms. Full, half, and quarter-bridge devices.
h. Input Coupling (software select/read): AC or DC
i Input Level: +/-0.001 to +/-10 Volt
j. Input Protection: +/-50 Volt
k. Input Impedance: >15x10^6 Ohm
l. Input Shielding (software select/read): Open, grounded, or driven.
m. Filter & Cutoffs (software select/read): 6 pole Bessel, at least 500 frequency cutoffs from 5 to 128,000Hz
n. Filter bypass (software select/read)
o. Frequency Response (filtered): 5 to 128,000 Hz
p. Frequency Response (filter bypassed): DC to 250,000 Hz
q. Gain/Scaling (software select/read): at least 16 steps such as 1/16, 1/8, 1/4, 1/2, 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048, 4096, and 8192x.
r. Output Level: +/-10 Volt
s. Output Current: +/-20 mA
t. Output Impedance: 50 Ohm
u. Interchannel Crosstalk: >-80dB
v. Calibration, Performance and Health: Software select/read. Onboard automatic bridge balance (requires <250ms/channel), automatic DC offset (requires <250ms/channel), shunt calibration, shorted and zero excitation noise levels, overload, and other fault detection. External source test inputs for comprehensive channel calibration and field performance verification signals.
w. Identification (software read): Onboard information available including but not limited to model, serial number, firmware version, configuration and installed options.

4.2.2. Mainframe Mainframe enclosures shall house the signal conditioning card modules, which shall be fully interchangeable between mainframes and card slots depending on required types and quantities of signal conditioning channels. The mainframes shall have at least the following characteristics.

4.2.2.1. Capacity. At least two sizes of mainframe are desired to accommodate YTC's goal to field three system configurations. Except channel count, all performance, functions, features, commands, and responses shall be common to all mainframes. Mainframes shall provide at least the following channel count capacities.

a. Mainframe for Basic or Intermediate Systems: 8 to 32 channels
b. Mainframe for Intermediate or Large Systems: 64 to 128 channels

4.2.2.2. Interface/Control. Each mainframe shall interface the system computer and calibration instruments with all functions and responses of itself, all slave mainframes, and all installed signal conditioners. The interface shall provide rapid communication between the ballistic system PC and signal conditioning equipment. Interface and control characteristics shall include, but are not limited to:

a. Remote Interface Port Type: 10/100baseT, TCP/IP
b. Controller On-Board Memory: Non-volatile. Provides readable identification including model(s), serial number(s), firmware version, etc.
c. Controller Power On Tests: Perform power on self tests of memory, registers, signal paths, and communications with results available to the system computer. System computer shall be able to initiate power on tests at any time.
d. Mainframe/Signal Conditioning Control: The controller shall enable all required identification, tests, settings, calibrations, and result reporting of the mainframe and each signal conditioner channel.

4.2.2.3. Calibration. Each mainframe and on board controller shall enable comprehensive and abbreviated signal conditioner calibration, rapid setup, and rapid performance verification.

4.2.2.4. Physical. Physical characteristics of the mainframe shall include the following:

a. Mounting: Standard 19-inch wide rack mounted.

b. Card Module Install/Remove: From front.

c. Input/Output Connections: Stay connected at rear for card removal and reinstallation.

d. Cooling: Adequate or better for a full complement of modules that generate the highest cooling load. Cooling fan(s) monitored and alarm produced for fan speed faults.

e. Cooling Air Filtration: Filters included to reduce/eliminate dust infiltration. Filters shall be readily accessed for cleaning or replacement

f. Temperature Monitor: Mainframe monitors temperature and produces an over-temperature alarm.

g. Main Power Switch: Located on front panel.

h. Power Supply: 120 VAC, 50/60 Hz input. Internal low-noise power supply for fans, controller(s), and full complement of cards.

i. Power Monitor: Internal monitoring and reporting of power supply levels or faults.

4.3. **Analog to Digital Conversion/Digitization.** The digitizer shall provide conversion of analog signals into numeric values available to the ballistic system PC. The digitizer shall have a high channel density and include readily added or removed digitization modules supported by a mainframe chassis. The digitizer shall allow use of multiple units to expand channel quantities to 256 (or more). The digitizer shall support and be part of the system calibration, performance checks, and verifications of all channels. Additional digitizer characteristics are outlined as follows by channel and mainframe.

4.3.1. <u>Channel</u>

4.3.1.1. Input Type: Fully isolated, differential desired

4.3.1.2. Input Coupling (software select/read): AC and DC

4.3.1.3. Input Impedance: >=1,000,000 Ohms

4.3.1.4. Input Voltage Range: +/-10 Volts

4.3.1.5. Input Overvoltage Protection (minimum): +/-24 Volts

4.3.1.6. Sampling Rate (software select/read): 1 to 500,000 samples per second minimum. 1 to 1,000,000 samples per second desired. At least 41 steps such as 1, 1.25, 2, 2.5, 4, 5, 8, 10, 12.5, 20, 25, 40, 50, .....500,000 S/s.

4.3.1.7. Sample Resolution/Dynamic Range: 16 bits minimum

4.3.1.8. Sampling Method: All channels simultaneous. FIFO buffered for desired sample spanning a user-selected pre- and post-trigger period.

4.3.1.9. Sample Memory (software select/read): 8 million samples per channel minimum. Memory allocations shall be assigned/read by software. Desire non-volatile memory to survive power outage or sag. Desire 16 million samples or higher per channel. Desire software allocated memory segmenting for automatic re-arming and re-triggering a fixed number of times to collect an expected burst of events.

4.3.1.10. Measurement Uncertainty (maximum: +/-2 LSB

4.3.1.11. Interchannel Skew (maximum): +/-5 ns, all channels

4.3.1.12. Trigger - Analog Input (software select/read): Any signal channel combination.

4.3.1.13. Trigger - Analog Input (software select/read): Any level in channel range.

4.3.1.14. Trigger - Analog Input (software select/read): Pos. or neg. slope.

4.3.1.15. Trigger - Digital I/O Type: 5 Volt TTL

4.3.1.16. Trigger - Digital I/O Event (software select/read): Acts on pulse width >=10 ns. Selectable rising or falling pulse.

4.3.1.17. Trigger - Digital Input (software select/read): >= 1 per 4 channels from mainframe.

4.3.1.18. Trigger - Digital Output (software select/read): >= 1 per 4 channels to mainframe.

4.3.2 <u>Mainframe</u> Mainframe enclosures shall house and support the digitizer modules, which shall be interchangeable between any mainframes and card slots depending on required channel capacities. Each mainframe shall interface the system computer and calibration instruments with all functions and responses of itself, all slaved mainframes, and all installed digitizers. The mainframes shall have at least the following characteristics.

4.3.2.1. Capacity. At least two sizes of mainframe are desired to accommodate YTC's goal to field three system configurations. Except channel count, all performance, functions, features, commands, and responses shall be common to all mainframes. Mainframes shall provide at least the following channel count capacities.

a. Mainframe for Basic or Intermediate Systems: 8 to 32 channels
b. Mainframe for Intermediate or Large Systems: 64 to 128 channels

4.3.2.2. Interface. The interface shall provide rapid communication and bulk data transfer between the system PC and digitizing equipment. Interface throughput to local storage on the system PC hard disk shall be at least 20 MS/s continuous and 30 MS/s peak while any critical tasks remain active. Faster throughput is desired.

4.3.2.3. Controller. Each mainframe controller shall direct the command and response communications between itself, all slaved mainframes, and the system PC. The mainframe controller shall direct all clock and triggering signals, digitizer support functions, and report settings, status, and any faults. Control functions include, but are not limited to the following.

a. Mainframe Power On Tests: Perform power on self-tests of memory, registers, signal paths, communications, with results available to the system computer. Auto-identify any installed digitizer modules. System computer shall be able to initiate power on tests at any time.
b. Controller On-Board Memory: Non-volatile. Provides readable identification including model(s), serial number(s), firmware version, etc. of controller and mainframe.
c. Mainframe Digitizers (software select/read): The controller shall route commands and responses between other mainframes, digitizers and the system PC for identification, settings, status, and calibrations of channel.
d. Clock (software select/read): Sampling clock synchronization, source, and distribution shall be directed by the controller with status reporting.
e. Triggering (software select/read) Internal and external trigger sources and distribution shall be directed by the controller with status reporting.
f. Other Support Functions (software read): The controller shall supervise all digitizer support functions such as power supplies, cooling, and fault limits, and report any warning or fault conditions.

4.3.2.4. Triggering. A trigger signal to a digitizer shall establish its start and stop points of the recorded sample. The mainframe shall provide and control internal and external trigger inputs and outputs. All trigger routing and status reporting shall be accomplished via software. Trigger characteristics shall include:

a. Internal A/D Sources: Any digitizer analog input channel.
b. Desired - Internal Digital Sources: Any digital timing/sequencing function included in the mainframe or provided by a fully compatible module.
c. External Digital Inputs (minimum): Two (2), 5 Volt TTL type.
d. External Input Response: On rising or falling, positive or negative, 10 ns or greater pulse width.
e. Outputs - Internal: One (1) distinct trigger available per four (4) channels. Grouping is acceptable.
f. Outputs - External (minimum): Two (2) distinct, generic, 5 Volt TTL type plus others required by any slaved mainframe.
g. Composite Outputs: Calculate at least one (1) logical function of up to four (4) inputs/sources of any type.
h. Calibration Triggers: Software shall produce triggers to

digitizers during system calibration and verification checks. Input shall be via calibration instrument signals to analog inputs or internal digital source (desired).

i. Trigger delay/skew (maximum): +/-5 ns all channels

4.3.2.5 Sampling Clock. The mainframe or its installed clock module shall provide a high-stability pulse signal to the digitizers for precisely timed, synchronous, interchannel sampling. Additional characteristics follow.

a. Internal Clock Rate: 10 MPPS
b. Internal Clock Rate Stability: <=25 (<0.5 desired) ppm
c. External Clock Source: 10 MPPS, 5 Volt TTL, BNC connector.
d. External Output: BNC connector, levels to match slave mainframe requirements.

4.3.2.6. Calibration. Each digitizer shall enable comprehensive calibration, rapid setup, and rapid performance verification.

4.3.2.4. Physical. Physical characteristics of the mainframe shall include the following:

a. Mounting: Standard 19-inch wide rack mounted.
b. Card Module Install/Remove: From front.
c. Cooling: Adequate or better for a full complement of modules that generate the highest cooling load. Cooling fan(s) monitored and alarm produced for fan speed faults.
d. Cooling Air Filtration: Filters included to reduce/eliminate dust infiltration. Filters shall be readily accessed for cleaning or replacement.
e. Temperature Monitor: Mainframe monitors temperature and produces an over-temperature alarm.
f. Main Power Switch: Located on front panel.
g. Power Supply: 120 VAC, 50/60 Hz input. Internal low-noise power supply for fans, controller(s), and full complement of cards.
h. Power Monitor: Internal monitoring and reporting of power supply levels or faults.

4.4. **Calibration.** You shall provide instruments to calibrate and verify the signal conditioning and digitizing equipment according to accepted calibration practices. All calibration instruments shall be readily calibrated by the Test Measurement and Diagnostic Equipment Support Laboratory, Yuma (or other certified laboratory) to assure traceability to NIST standards. These calibration instruments shall be controlled by the system PC to provide comprehensive calibration and rapid (abbreviated) field performance checks of all desired channels. All calibration instruments shall have onboard memory and settings available for the system PC to direct, confirm, and report the calibration instruments' usage and identification characteristics. All calibration instruments shall be rack-mounted and readily removed and replaced in the ballistic system, without disruption of other equipment, by others of the same model as they rotate through individual periodic calibration cycles. YTC anticipates each ballistic system will require the following high resolution instruments.

4.4.1. <u>Digital Multimeter.</u>

4.4.2. <u>Arbitrary Waveform Generator.</u>

4.4.3. <u>Frequency Counter.</u> Note: A frequency counter may not be required if chronography equipment (10 MPPS output synced to UTC) is found to be an inherently more direct, effective, and traceable clock source.

4.5. **Doppler Velocimeters.** GFE. YTC will provide two types of radar velocimeter. The ballistic system shall accommodate and operate concurrently and effectively with both types of velocimeters connected to two antennas. A single velocimeter with two antennas will be used at one time. Rack space shall be provided to accommodate either type of velocimeter as unmounted and drawered and readily removed for service or relocation to another system. Concurrent ballistic system operation shall be at full performance providing all functions of at least a basic type (8 channel) configuration. A single field technician shall be able to readily control the entire system and produce reliable data during a basic mission consisting of two velocities, two pressure and six other channels of transducer data, and T0 and t4. No degradation shall occur in operation of the ballistic system or the velocimeter control/analysis applications. Velocimeter types consist of:

4.5.1. Weibel W-700. W-700 Analyzer User's Guide. Weibel Scientific A/G is the OEM of the W-700, RemDopp, and most of the antennas and associated hardware. YTC highly desires an equivalent replacement for RemDopp's control and display functions. You are strongly encouraged to quote an option to replace RemDopp with equivalent functions in the ballistic system.

4.5.2. Infinition JB-5000. Infinition Test Center User Guide. Infinition Inc. is the OEM of the JB-5000, TestCenter, and YTC's currently used BR series antennas.

4.6. **Sequencing.** The ballistic system shall provide selections of precisely timed digital outputs and corresponding relay contact closures that will be used to initiate or stop various actions during a countdown. Examples of sequenced actions include early startup of other systems such as tracking mounts and film cameras, gun firing (at time zero), and starting other instrumentation such as flash x-ray shortly after time-zero. Sequencer shall be controlled by the system PC and provide onboard memory and settings available to the system application to direct, confirm, and log setting and hardware identification characteristics. Sequencing equipment shall be directly rack-mounted or slotted in the digitizer mainframe. Additional requirements are as follows.

4.6.1 All Outputs. The following applies to each sequencer output regardless of type.

4.6.1.1. Quantity: Eight (8) sequenced output pairs of one (1) each TTL and contact closure. YTC desires 16 pairs. Each pair responds to the same control setting.
4.6.1.2. Setup and Control (software select/read): Controlled by application. Any combination of eight (8) pairs output at any time. Any pair assigned as 'time zero'. Start initiated by technician via software starting countdown.
4.6.1.3 Range (minimum): +/- 1000 seconds from time zero output.
4.6.1.4. Time On (software select/read): 0.01 to 1000 ms
4.6.1.5. Aborts: Equipment shall include and allow output disabling in case of a countdown abort. Provide a manual countdown abort 'mushroom' switch to halt and reset a countdown. The hardware shall respond likewise to an abort initiated by the technician via software.

4.6.2. Digital Outputs. The following applies to each digital output.

4.6.2.1. Level: +5 Volt TTL
4.6.2.2. Uncertainty: < 1 microsecond between programmed and actual times of any outputs.

4.6.3. Relay Closures. The following applies to each relay output.

4.6.3.1. Type: SPDT (DPDT desired)
4.6.3.2. Contacts Rating: 8 Amps, 30 VDC (100 VDC desired)
4.6.3.3. Switching Delay (maximum): 10 ms (less desired)

4.7. **Chronography.** GFE. YTC plans to provide two models of GFE timing hardware to integrate with the ballistic system for chronography and UTC time reference. One item was recently developed and delivered to YTC. The other item has just entered software development and planned for introduction in a future upgrade. You may select other hardware if a strong rationale is provided for its use. Lead GFE particulars are as follows:

4.7.1. ITS 6115G-TSM. Reference www.itsAmerica.com.

4.7.2. Ballistic Chronographs. FUTURE OPTION - NOT PART OF SCOPE. YTC expects to add a function to the ballistic system to serve as the up-range participant in split system chronography mode. This mode is required for typical fuze/flight time measurements where the target area is beyond line of sight, many kilometers from the weapon. In split mode, the ballistic system will serve as the 'slave' chronograph that simply relays the muzzle exit time over the network to the downrange master chronograph (a.k.a. lunchbox). Based on muzzle exit, fuze setting, and other timing information, the master chronograph will open the predicted fuze/flight time event acceptance window, record fuze IRD trigger event times, calculate and record fuze/flight time results, and copy them to the data center for archival and distribution.

4.8. **Positioner.** The ballistic system shall control at least two (four desired) ruggedized pan/tilt positioners located adjacent to a weapon or launcher. The positioners shall provide timely, automatic re-alignment of instruments requiring a particular orientation to a weapon, launcher, or expected trajectory. Positioners shall also provide status, settings, and axis positions to the ballistic system. Re-alignments shall accommodate predicted weapon aiming changes directed by its fire control system during burst firings including MRSI missions. Mounted instruments are likely to include velocimeter antennas and IR flash detectors. Positioners shall provide the following.

4.8.1. Payload and Motion

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|---|---|---|---|
| 4.8.1.1. | Payload: | Up to 50 pounds, slight to moderate imbalance on tilt axis. | |
| 4.8.1.2. | Pan Range: | +/- 160 | degrees |
| 4.8.1.3. | Tilt Range: | -30 to +90 | degrees from level |
| 4.8.1.4. | Pan and Tilt Speed Range (software select/read): | 1 to 50 | degrees per second |
| 4.8.1.5 | Pan and Tilt Position Uncertainty: | <+/- 0.1 | degrees |
| 4.8.1.6 | Command Transmit/Response Latency: | < 50 | ms (to start motion) |
| 4.8.1.7 | Operating Duty Cycle: | 95 | % |

4.8.2. Environmental The positioners and associated support equipment must operate reliably in an outdoor desert test environment that is significantly harsher than for the remainder of the system. Also, the units may be required in arctic or cold chamber applications at low temperatures. Usage will typically require locations close to weapons or launch platforms which produce radiant flash, blast over pressure, and movements of dust and sand. The positioner shall operate effectively in and survive a usage environment characterized as follows.

| | | | |
|---|---|---|---|
| 4.8.2.1. | Ambient Temperature Range (operating): | -20 to 120 | degrees F |
| 4.8.2.2. | Ambient Temperature Range (non-operating): | -30 to 150 | degrees F |
| 4.8.2.3 | Solar Irradiation: | At YTC, approximately 300 BTU/hour/square foot. | |
| 4.8.2.4. | Noise/Blast (shock impulse pressure): | up to 10 | psig peak |
| 4.8.2.5. | Shock (mechanical impulse, half sine): | 30 | g peak, 10 ms |
| 4.8.2.6. | Vibration (mechanical): | Off-road/dirt road sustained transport as loose cargo. | |
| 4.8.2.7. | Contaminants (solid): | Frequent wind-blown dust and sand. | |
| 4.8.2.8. | Contaminants (liquid): | Infrequent wind-blown rain. | |

4.8.3 Power/Control/Interface Positioners will be located semi-remotely from the ballistic system. Power supply, cable(s), and interface(s) shall support effective operation across a significant distance. Positioner controller, interface, and associated equipment shall allow reliable, timely, and complete control of the positioner via the system application. Detailed requirements and desires follow.

| | | | |
|---|---|---|---|
| 4.8.3.1. | Distance/Cable Length(s): | 100 | meters |
| 4.8.3.2. | Cable Type (desired): | Cat 5 | or better |
| 4.8.3.3. | Interface Type (desired): | Ethernet | TCP/IP |
| 4.8.3.4. | Interface Connector (desired): | RJ-45 | ruggedized |

4.9. **System PC.** You shall provide a computer that integrates and efficiently accomplishes all system functions. Performance of the PC shall allow the ballistic system to meet all performance and functional requirements. PC performance shall provide reserve capabilities for future extension of ballistic system hardware control and data processing functions. The system PC shall satisfy the following additional requirements.

4.9.1. <u>Computer.</u> Rugged, 19-inch wide, rack-mounted type. The PC shall also have adequate power supply and cooling for a full complement of function cards and shall include readily serviceable cooling air filters to reduce dust infiltration. I/O ports shall include at least one parallel printer, at least two each uncommitted USB receptacles on the front and rear-panels, and 10/100/1000 baseT standard ethernet RJ-45 socket. A single computer and processor are highly desired. Reserve capacity (>>50%) is also highly desired for future upgrades in producing data and for significant expansions in post processing data manipulation.

4.9.2. <u>Monitors.</u> Dual 19" LCD flat panel monitors. Standard desktop type. Include video cable extensions to span at least 18 feet. YTC desires metallic or substantially rigid plastic monitor bases for planned bolt-down to shock mounts on a table top.

4.9.3. <u>Keyboard/Mouse.</u> Standard Windows-compatible type for desktop use. Include cable extensions to span at least 18 feet. Wireless desired for use in any orientation up to 12 feet from front of rack. If used, wireless devices shall operate as effectively as similar wired units and shall not degrade ballistic system performance.

4.9.4. <u>Operating System</u> GFE. A minimal or no operating system shall be provided, whichever is least expensive. YTC maintains a site license and baseline configuration image for Windows XP Professional (or the latest Windows OS accepted/mandated for Government use). Although no OS is required in the delivery, the ballistic system shall be designed to operate with MicroSoft Windows XP Professional. Design shall include practices and provisions for the entire ballistic system to readily function with future versions of the Windows OS. Soon after delivery, YTC will re-install its OS and baseline on the boot drive of each system PC. YTC will then re-install the ballistic system application and other applications prior to starting acceptance checks.

4.9.5. <u>Other Software</u> GFE. YTC also maintains site licenses including MicroSoft Office XP Professional and Corporate Symantec/Norton AntiVirus. Soon after delivery, YTC will install these applications on each system PC. The ballistic system shall effectively and concurrently operate with any resident or required portions of these applications. You may exploit any capabilities of these applications for system performance or functions. Although the data display and manipulation functions may be migrated to a web-based capability via a future option, YTC does not intend to use any ballistic system for user web browsing or email functions.

4.10. **Communications, Interfaces, and Miscellaneous.** You shall utilize commercial, widely-used, industry standard communication and interface hardware. Switching hardware shall include intelligent self-management and allow flexible switch management via the system PC. YTC highly desires, in order of preference, use of ethernet (TCP/IP), USB, IEEE1394, GPIB, or other common, high performance interfaces. Transfer rate, low noise, reliability, ease of maintenance, common replacement alternatives, cost, and very long-term parts and firmware support shall be key objectives in providing hardware such as:

a. Control interfaces.
b. Switches (including routers or hubs)
c. Connectors and cables.
d. Power supplies, and other items required to support the system.

4.11. **UPS.** The system shall include an uninterruptible power supply for key data collection equipment such as the TSMU, signal conditioner, digitizer, velocimeters, and system PC. In case of a power loss, the UPS shall sustain power to finish any pending data transfers, record the data on the PC, and allow an orderly system shutdown.  YTC estimates at least 10 minutes of operation will be required.

4.12. **Racks.** Provide standard, steel, 19-inch wide racks that properly support all equipment.  Each rack or set of racks shall have the following characteristics.

a. Nominal dimensions: 72 H x 22.5 W x 26 D inches.
b. Panels on tops and exterior sides only (no back nor front doors nor interior panels).
c. Adequate natural (or forced) circulation to support cooling for all equipment.
d. Substantial, flat bases with removable leveling feet that leave no protrusions for use in buildings or bolted to gliding vibration/shock isolation platforms in truck shelters.
e. 120 VAC receptacle strip(s), with overload breaker(s), for all equipment plus spares.
f. No more than 3 racks shall be used for any system.
g. Desire not more than 1 rack per basic system.
h. Desire not more than 2 racks per intermediate system.
i. 19 W x 18 H inches minimum of rack reserve open space for other and future equipment.

4.13. **Environmental.** The ballistic system shall be fully functional in an indoor environment such as a site-built or prefabricated building, or an operations shelter mounted on a truck chassis.  Buildings and shelters are typically located at remote desert firing sites accessed by gravel roads or cross-country trails. The system will be routinely exposed to transport vibration, high ambient temperatures, dust, blast-induced shock and vibration, power distribution and generator noise, bumps and outages, and network communication outages.  Also, the systems may be required in arctic or cold chamber applications at low temperatures.  Unless outlined for a particular item, the system shall operate effectively in and survive a usage environment characterized as follows.

| | | | |
|---|---|---|---|
| 4.13.1. | Ambient Temperature Range (operating): | 40 to 110 | degrees F |
| 4.13.2. | Ambient Temperature Range (non-operating): | 0 to 140 | degrees F |
| 4.13.3. | Noise/Blast (shock impulse pressure): | up to 1 | psig peak |
| 4.13.4. | Shock, Half-sine Impulse - Operating (non-operating): | 5 (20) | g peak, 10 ms |
| 4.13.5. | Vibration (non-operating): | Sustained truck transport over gravel road. | |
| 4.13.6. | Contaminants (solid): | Persistent dust infiltration. | |
| 4.13.7. | Power (from grid and generator): | 110-130 VAC, single phase, 55-65 HZ | |

5. **FUNCTIONAL REQUIREMENTS** Ballistic system functions include but are not limited to initializing, configuring, verifying, arming, and triggering hardware as well as transferring, storing, displaying, analyzing, and manipulating data for up to 128 channels.  YTC desires the capability to link multiple systems for expansion to 256 (or more) channels.

5.1. **Self-Checks and Initialization.** The system shall scan for and reset hardware, load important settings, perform self-checks, and determine operational status at startup.  These include, but are not limited to the following.

5.1.1. <u>Environment.</u> Important settings and environment variables shall be loaded from readily edited text files such as "*.ini" and/or others at startup.  Examples include data production default settings, local, working, and archival data drive and path designations, usernames, domain name, and calibration data and locations.

5.1.2. <u>Inventory.</u> The system application shall scan for available instrumentation to create a resource list of equipment ready for employment by the user.  The scan shall be comprehensive using dynamic addressing (plug and play) of hardware to include all required instrumentation on any interface, bus, or communications link.  The resource list shall include any significant identification and status information for each item.  Status information shall include health responses and look-up of calibration void dates and any necessary calibration values.  YTC desires to also use the data center as a secondary search location for calibration data in the event instrument modules are moved between systems.

5.1.3. <u>Network.</u> Determine ethernet operability and quality, display status with color coded graphic indicator and text. This indicator shall update regularly, such as approximately every minute, and shall remain visible at all times. In case of ethernet loss at any time, the system shall continue to function no reduction in performance. If any additional need for operator intervention results, it shall be minimized.

5.1.4. Time Source. Restore defaults as needed. Determine and indicate GPS time lock status and time quality. The system shall display status and timing quality with color-coded graphic indicator(s) and text, or equal or better method. This indicator(s) shall update regularly, such as approximately every minute, and shall remain visible at all times. All data shall typically reference to UTC (formerly GMT) at full source resolution, but shall allow conversion to local time (via supervisory utility). In addition, this function shall update the PC with the correct local date and time at startup in order to insure correct administration of setup and data folders and files.

5.2. **Utilities.**

5.2.1. Supervisory. Certain functions and controls shall be limited to use by senior technicians and maintenance personnel logged in locally or remotely to the system. As a minimum, these functions shall include:

5.2.1.1. Calibration. The system application shall set up and execute an effective, comprehensive calibration of the digitizing and signal conditioning channels. Calibration will be performed at an established firing facility or the central work area to help assure ready access and reliable power and network connections. Each system will typically undergo calibration annually, which will very likely follow calibration of one or more of the reference instruments. The following functions shall be provided. Desired features are included.

a. A calibration status report shall be available for all reference and data production instruments to show identification, calibration void dates, and any other data needed to manage calibrations. Text color, background, or other attributes shall be used to indicate items that have acceptable, minimal, and expired calibration days remaining. This report shall be available to any authorized user.
b. The calibration function shall provide previous setup recall, controls, and indicators for the senior technician to readily select or scale any combination of mode(s), mainframes and channels, save the setup, and initiate a complete or partial system calibration. The system shall complete the calibration, including report, unattended with no further input required by personnel. Total calibration time shall not exceed 15 minutes per channel. YTC desires calibration completion in less than 10 minutes per channel. Calibrated hardware modules shall be individually moveable between systems without need for recalibration. Networked and manual methods shall be provided for any needed calibration records to accompany any associated module.
c. Calibration results shall be recorded in a report that includes all significant information such as pass or fail, date, report number, item description, manufacturer, model number, serial number, bar code, ranges, frequencies, durations, levels, impedances, offsets, results, calibration void date, traceability reference(s) manufacturer, model number, serial number, calibration void date, uncertainty estimates, and other equipment used, senior technician name, and remarks. YTC desires that the calibration results are also recorded at the data center for later reference in tracking instrument status and indications of aging. YTC desires use of the data center for migrating calibration results with instrument cards when they move between systems or return from maintenance or repair.
d. Calibration shall provide traceability to NIST via the reference instruments.
e. A function(s) shall be provided to manage the reference instruments' calibrations. These items are part of the YTC calibration program and are calibrated on a regular basis. This function shall include entering new calibration void dates for reference instruments, warning all operators at startup of imminent or expired calibrations, and keeping a log of which reference instruments were used for a given period. YTC desires extension of the calibration manager to all instruments.

5.2.1.2. System Settings. The application shall include a function(s) to edit key, advanced, or otherwise controlled system parameters that change infrequently. Key parameters shall be displayed but inactive for the user in utilities or mission setup screens to aid field troubleshooting. These settings shall be self-explanatory and in a file(s) that are text-based and can be edited locally or remotely using Notepad or a similar editor. These settings shall also be able to update or synchronize to a master setup via the network. Examples include:

a. Addresses that must be assigned statically.
b. Hardware identifications or identities.
c. Test director and technician name listings.
d. Archive, logging, and transducer data lookup paths.
e. Data quality (spike, over range, noise level, ...) and system verification pass/fail limits.
f. Data products/formats required from velocimeters.
g. Prudent sequencer abort options settings and verification of setting behavior.

5.2.1.3. Time of Day. A control shall be provided to enter a value, typically in +/- NN hours, used by the system to convert UTC time to local time. A value of zero (UTC time) shall be the default.

5.2.2. Pre/Post-Mission System Verification. The application shall include a function(s) for the user to check calibration status and, after warm-up, perform rapid pre- and post-mission system health checks. The user shall be able to select which channels, modes, and modules will be verified. Built in self-test and diagnostic features shall be exploited for the signal conditioners, digitizers, and any other hardware with these capabilities. These health checks shall verify system performance, response, gain, span and offset settings, noise levels, and acceptable impedances compared to predetermined limits. YTC plans to run the system check in the field at the start of each day, prior to the first round, and at day's end, after the last round. A report of results shall be displayed and recorded with warnings or faults annotated. The checks shall require no more than approximately 5 seconds per channel to complete. Concurrent or simultaneous checks on multiple channels is allowable and encouraged to get maximum verification in minimum time. Examples of desired performance verifications are presented at Appendix A.

5.2.3. Remote Control/Access. The ballistic system shall provide access to monitor calibration, verification, and setup information, and to operate the system and display data results remotely. These features will be used by senior electronics and information systems technicians to remotely check system status and help diagnose and correct field problems. Remote control is also required when a system must be operated unmanned in a potentially hazardous situation.

5.3. **Mission Setup.** The system shall provide controls and indicators for the user to set, record, recall, and allow adjustments in operational parameters for the system and for each mission. User inputs shall be checked and prompted for correction of invalid settings for the intended usage. Indicator attributes and warnings shall alert the user for any instruments available or selected that are near or past their calibration expiration date. Parameters may be enabled or disabled based on available instruments and selection of operational mode(s). At least the following setup functions shall be provided and managed for setup.

5.3.1. Load Previous Mission. Standard file browsers shall at least allow the user to load, edit, and store setup files via a File menu containing Open, Save, and Save-As functions.

5.3.2. Setup - Administrative. Provide entries for user-supplied information set at the start of a mission. This information may be changed by the user infrequently during the mission. This information shall be automatically copied to or merged with data from all instruments, such as velocimeters, to eliminate duplicate entries of the same information.

a. Technician: Name of user(s) from login. Selection required.
b. Test Director: Select name from list. Selection required. This is a primary piece of information used to manage, identify, and record test data.
c. SR Number: Schedule Request Number - Alpha-numeric entry.

d. JONO: Job Order Number - Alpha-numeric entry.
e. ADSS Number: Army Decision Support System Number - Alpha-numeric entry.
f. Project/Item: Name of program or item under test. Required alpha-numeric entry.
g. *Test Location: Name of test site. Required alpha-numeric entry.
h. Classification: Security classification. Selection required from list. UNCLASSIFIED (default), PROPRIETARY, CONFIDENTIAL, SECRET, TOP SECRET
i. *Weapon: Model/type & ID number. Alpha-numeric entry.
j. *Tube Number: Gun tube serial number. Alpha-numeric entry.
k. *Propelling Charge: Propelling charge model. Alpha-numeric entry.
l. *Propellant Temp.: Propelling charge temperature. Numeric entry.
m. *Projectile: Projectile model/type. Alpha-Numeric entry
n. *Projectile Temp.: Numeric entry.
o. *Weapon QE: Quadrant Elevation (-300 to +1600). Numeric.
p. *Weapon Traverse: 0 center-default (-3200 to +3200). Numeric.
q. *Remarks: Mission setup Comments. Alpha-numeric entry.
r. Round Number: Tube round number. Starting round number of the mission. Required entry. The round# shall auto-increment after every triggered acquisition without operator intervention. The Round# shall be manually adjustable by the operator. The control for the next Round# shall be available at all times. Under no circumstance shall changing the Round# cause data to be overwritten. The Round# is a primary piece of information used to manage, identify, and record test data.

* User may append several times during a mission because of weapon moves and ammunition gun tube changes.

5.3.3. <u>Setup - Analog Channels.</u> The system shall display all available channels. Control and indicator screens shall be readily accessed by tabs or other means to enable any combination of channels, select any combination, set their operational mode(s), signal conditioning, digitization, and triggering parameters. The system shall include auto-configure features. With minimal user inputs for a channel, the system shall optimize the remaining settings and then allow any valid user adjustments. Graphic and numeric affects of settings changes shall update immediately in "preview" and "channel metrics" displays. The full feature sets of the instruments shall be made available to the user. Additional functions shall include, but are not limited to:

a. Selection: Provide selection options to user to quickly perform channel setup for all channels, individual modules, individual groups, or individual channels. The system shall allow mid-mission addition or removal of channels.
b. Grouping: Provide selection from a list for the typical channel types which shall include: Breech and Chamber Pressures, Generic Pressures, Microphones, Displacements and Voltages, Accelerometers, Strains, Forces, Trigger and Time Zero and Muzzle Exit, and Other.
c. Calibration: Mark/highlight and disable any channel with expired calibration. Allow operator to override disabled channel after warnings. Results in void calibration flag in data.
d. Channel Naming: A channel naming scheme shall be used which allows the user to readily associate transducer inputs, hardware, system channel numbers, and measurand descriptions. The user will enter the measurand description. YTC desires compound channel names. Digitizer channel numbers shall be formatted as Ch001-ChNNN.
e. Gage Factor Input: Provide user entry to name the specific EU (psig, kPa, g, u-strain, etc.) represented by the gage output, and the type of gage output (pC, uV/volt, volts, mA). System shall allow mid-mission gage replacements. The system shall accept gage factors provided via:

(1) Calibration Report. This applies primarily to YTC-manufactured, Tourmaline charge mode sensors. The system shall open and display a text-based calibration report file from a calibration server. File selection shall be based on transducer model, serial number, and date. User verifies the report file agrees with the printed calibration report. A notional example of the report is presented at Appendix B. YTC also desires the ability to read the calibration file locally from portable media such as a USB RAM drive. Up to 100 (EU, output) data pairs shall be read. Depending on sample size, a best fit Nth (2<N<16) order polynomial and correlation coefficient shall be calculated. If correlation is within acceptable limits, the system shall record the polynomial order and coefficients, use it's best fit slope to set hardware, and use it later during data recording to capture best estimate measurements.

(2) Gage Factor: Standard, best fit slope, single gage factor (1/sensitivity).

(3) Gage Factor-Offset: Slope-intercept parameters for best fit estimate of gage with a zero stimulus offset.

f. TEDS: NOT PART OF SCOPE - FUTURE OPTION Automatically recognize and read transducer electronic data sheet compliant transducers connected to TEDS-capable signal conditioners.

g. Amplifier: Full user controls and indicators to select channel input types, modes, and coupling, and to modify auto-configured settings for excitation, gains, filtering, and so on.

h. Triggering: Exploit all triggering modes available in the digitizers including composite/Boolean selections of external analog sources and external and internal digital sources. Threshold settings include at least levels and slopes. Any digitizer trigger master groups shall also be available for selection and use in synchronizing slaved groups.

i. Digitizer: Full user controls and indicators to select channel input ranges and coupling, and to modify auto-configured settings for filtering and sampling.

j. Setup Faults: Prevention and warning to the user for any invalid hardware configurations.

k. Channel Metrics: Provide page back and forth through the configuration pages, committing changes, to evaluate effect on ambient data in numeric and preview window(s) as sensors are exercised or simulated by upstream signal injection at the signal conditioner.. Numeric indicators and previews shall show the affects of settings on channel setup statistics such as:

(1) Maximum available ceiling in Engineering Units(EU).
(2) Input step accuracy in EU.
(3) Pre-Trigger Time, Post-Trigger Time, and Total Capture Time.
(4) Trigger level in Volts for External and EU for analog trigger thresholds.
(5) Other settings necessary to control the full feature set of the hardware.

l. Preview: Provide graphic preview window(s) to show continuous scaled data affects for the channels that are being configured. YTC encourages use of the data employment functions described in a following section. If needed, temporary reduction in sampling rate or decimation may be used to improve preview real time performance while checking and adjusting channel parameters.

5.3.4. Setup - Velocimeters. The system shall at least operate concurrently with either of two Doppler analyzers to exchange and utilize administrative information and data products. The system shall provide relevant administrative information directly to the analyzer or shall merge administrative data (operational or data recording function) into the appropriate areas of analyzer output products. YTC desires the system to take full control of the W-700 analyzer and perform the functions of RemDopp to set up the W-700s with parameters including, but not limited to, round number, antenna frequency and location, trigger source and timing, burst or triggered mode, ballistic velocity and time ranges of interest, regression method, and displays.

5.3.5. Setup - Sequencer. The system shall provide controls and indicators for the user to set the sequencing mode as relative to time-zero or time of day, assign output names and channels (one default name shall be "Time-Zero"), and enter pulse time start and duration settings. Setup shall include provisions to enable/disable any channel combination and exercise the sequencer to verify correct operation. YTC may temporarily divert chronograph channels or use other instruments to verify the sequencer outputs.

5.3.6. Setup - Chronography. The system shall provide controls and indicators to configure the TSMU and chronography functions. If another instrument(s) is provided, equal or better capabilities shall result.

5.3.6.1. Mode and Role. Select mode (stand alone or split) and role (only the "slave" role will be available for a ballistic system in split mode) for the required mission configuration:

a. Stand Alone: In this mode, fuze function or impact is within view of the weapon. The ballistic system obtains all timing inputs and produces and distributes time data products. Master and slave role selections are unavailable and disabled.
b. Split System: FUTURE OPTION - NOT PART OF SCOPE. In this mode, the ballistic system will send a small amount of time data to a down range (master) chronograph unit located near the impact area. The chronograph unit will capture the flight termination and produce TOF data.
c. Slave: FUTURE OPTION - NOT PART OF SCOPE. In this role, two systems work together, typically networked over long distance, to produce and distribute time data products. The master unit will typically operate down range, where the majority of timing events will occur. This system will serve as the "slave" only to capture and send T-0 and muzzle exit times to the down range "Master" unit for processing.

Note: The master station is desired at the down range location because the entire split system must also operate in the event of a network outage. Event times must be verbally transferred between the technicians in this situation. Fewer event times (at least 1) must be sent from the up range (slave station) firing site vice from the down range (master station) impact area (4).

5.3.6.2. Communication. FUTURE OPTION - NOT PART OF SCOPE. Select communication as "networked" or "verbal" for transfer of event times from slave to master when operating as a split chronography system. Default shall be networked.

5.3.6.3. Partner. FUTURE OPTION - NOT PART OF SCOPE. Select name of associated system from a pre-determined list. Valid entry is required to continue when operating in a split system. Verification shall be additionally confirmed during periodic network health checks.

5.3.6.4. Flight Parameters. Select configuration of channel connections and hold off periods for time of flight measurements.

a. Channels: Provide controls and indicators for the user to name and set event time channel inputs. Selectable inputs include Off, Time Zero, Muzzle Exit, FuzeChrono1, FuzeChrono2, FuzeChrono3, FuzeChrono4, and any additional auxiliary inputs if available. Individual infra-red detectors (IRDs) provide the event trigger signals for the fuze chronograph inputs.
b. Flight Timing: Provide controls to show and select manual/auto-arming (auto-arm enabled for T-0 and T-4 missions only), the expected time of flight, early enabled period, and late enabled period. These times shall be used to ignore early and late false event trigger signals from the IRDs. Inhibit periods are needed since the fuze chronograph IRDs sometimes false trigger because of birds, insects, or glints appearing in their field of view. Valid entries shall be required in order to continue when any FuzeChrono channel is selected. One set of entries shall apply to all FuzeChrono channels.

5.3.7. Setup - Positioner. Provide controls and indicators for the user to manually move and monitor the positioners for calibration and checkouts, calibrate or register the positioners to reference elevation (tilt) and traverse (pan) angles, select manual or automatic moves to the next position in the active series, set required number of positions and pan and tilt angles for each position in each ordered movement series of up to 100 positions, establish and record a suite of desired movement series (movement scripts), select which script to show as available for the mission, and set pan and tilt angular rates. Provide a script selector to engage any available script during a mission.

5.3.8. Setup - Data Acquisition, Arming, Data Management, and Data Employment. Anticipated setup requirements are presented separately with these major operational functions.

5.4. **Data Acquisition.** As a minimum, the following functions shall be provided to measure dynamic, transient events. Measurements shall be taken at desired times, typically during a daily mission that will fire up to 100 rounds of large munitions or several hundred rounds of smaller caliber ammunition. The functions shall record the measurements on the system PC in a timely manner for rapid re-arming and subsequent data analysis and distribution.

5.4.1. Arming. The system shall provide an arming manager to arm or inhibit instruments for data collection, sequencing, and timing. The arming manager shall arm all desired hardware based on a single user input (spacebar/button click) or event time (such as muzzle exit) plus a preset delay for burst or auto-arming mode. The arming manager shall provide a similar input to start the sequencer, Although required, if the system does not provide inherent synchronization, the arming manager shall synchronize any separate clock signals. In addition, the arming manager shall reset the sequencer and disarm hardware in the event of a subsequent click of a software abort control or a hardware contact closure from a mushroom type abort switch. Options for manual, automatic/burst, and mixed mode arming shall be provided to accommodate slow (<1 round per minute) to fast (>1 round per second) cadences or rates of fire. Continuous data collection is a further option that shall be included if hardware capabilities permit it. Arming applies to manually or automatically controlling instruments and timing such as:

a. Enabling digitizer trigger(s).
b. Arming velocimeters to a ready state.
c. Starting the sequencer, including a countdown display.
d. Automatically moving the positioner head to its first position.
e. Arming the chronography functions.
f. Reversing or resetting all of the above states, except positioners, in case of an abort.

5.4.2. Acquisition. Once the system is armed, it shall typically begin recording data based on receipt of an external trigger. Additional requirements and desires follow.

5.4.2.1 Digitizers.

a. Re-try: YTC desires that the system re-read digitizer data if the transfer is incomplete, fails, or is interrupted by a fault or power problem.

b. Format: The initial proposal shall positively include a complete description of the data storage, file, and folder methodology. Digitizer source data shall be recorded in a file format considered the most effective, reliable, efficient, compact, portable, self-documenting, and industry-standard. YTC prefers header data imbedded with binary data, all in a binary file, unless a more effective method is proposed.

c. Header: YTC desires sufficient hardware identification and settings information for each channel stored in the data file(s) to allow: portability to direct client usage without the viewer, for complete channel path re-creation and auditing, and to permit potential future database or data mining projects.

d. File Management: Folder/file naming and content shall be unique and well-managed to preclude the possibility of overwriting data.

e. File Locations: Absolute priority shall be the immediate recording of data on the system PC. Archival at a pre-selected remote archive location shall be accomplished as processing time and network availability permit. During mission operations, virtually all other functions shall take precedence over archiving for use of system resources. Archiving activity shall be automatic and include a monitor to ensure all data is copied and alert the operator of delays, stops, or other failures.

5.4.2.2 Velocimeters. Native/fixed data sets from the velocimeters shall be recorded directly with administrative information pre-loaded or merged such that it will not impact any later reprocessing operations such as reloading, re-analysis with the same or modified parameters, re-display, and re-reporting/summarization.

5.4.2.3. Chronograph. Chronography functions shall record the entire mission's chronography results, including setup and change information, on a small number (YTC prefers < 5) of MicroSoft Excel worksheets. At least one worksheet shall be reserved for use by YTC. YTC will use the reserved sheet(s) for IRD setup and calculation of pointing angles. An emergency override shall be included to allow the technician to defeat the disable/enable window and immediately enable triggering in case of an unexpected change in the mission parameters such as a late announcement of changed fuze setting. The following chronography functions shall be provided.

a. Time Stamps: Capture event TOD data for the active channels. Channels include fire pulse (T0), muzzle exit, and four fuze chronograph IRD inputs. Any additional times shall be included if equipment other than the TSMU is selected to provide more inputs. Times shall be based on UTC, consistent with the entire system, unless a local time offset is set in the supervisory utility.

b. Analyses: Produce and record calculated data from event times:
   (1) t4 duration. Period of time from T0 to muzzle exit.
   (2) Time of Flight (TOF). Period of time from muzzle exit to fuze function or impact burst. Up to four (4) periods shall be reported, one for each IRD. Note: IRDs are typically set to view airbursts above an impact area for fuze timing (time of fuze function) measurements, but may be used to measure time of impact by viewing the surface of the impact area. The system shall determine whether any significant false events were reported and mark them with a readily noticed method such as with a distinct font or background color. The average of the acceptable times shall be calculated and recorded for each round.

c. Remarks: User shall be able to enter text remarks. YTC desires pre-established abbreviated text for the user to select. Examples include: Invalid Start or Stop, GPS Locked/Fly Wheeling, No Stop Time, Functioned Ground Impact, Warmer, Spotter, Test Round, and Chrono Inoperable. YTC desires the system to auto- annotate any significant, detected problems.

d. Display: The system shall display the finished version of the mission's on-going round by round Microsoft Excel chronography data sheet. The data sheet shall allow maximum feasible customization by senior and field technicians using standard Excel features. Display shall present the following as a minimum.
   (1) Descriptions. This area of the sheet shall accommodate organizational logos or graphics. One each near upper left and upper right corners. Logos shall be readily replaceable by senior technician and system maintenance personnel.
   (2) Titles. Data sheet name, organization name, security classification, and column headings.
   (3) Administrative. Data including program, ADSS No., JONO, SR No., test director, date, technician(s), and location name.
   (4) Legend. Descriptions of any abbreviations or attributes for test conditions or results.
   (5) Results. Tabular round by round chronography results. Data includes round number, T0, muzzle exit, t4, times of flight, average time of flight, remarks, and remaining fundamental IRD and auxiliary event timestamps.
   (6) Footer. Printouts only shall include system (current) date & time, page number, and security classification.

5.4.3 Post-Acquisition. YTC expects that some functions shall be required immediately or soon after the data acquisition period, these are considered near real time. Near real time functions include data recording, quick look display, and update of summary mission data statistics. Including source data recording, these near real time statistics shall all be accomplished in no more than one (1) second per channel after sampling is complete. YTC highly desires less than 0.5 second per channel. Further descriptions of these requirements follow in this and subsequent sections.

5.4.3.1. Over Range. Any signal conditioner or digitizer hardware that produces a signal over range or other operational fault indication shall be read. The fault information shall be annotated in the source data. YTC desires inheritance of this fault annotation from the source to any subsequent or derived data products.

5.4.3.2. Pan and Tilt. Although the positioners are not intended to provide data because their values are pre-determined by the active movement script, they will likely be commanded and expected to respond as a result of the acquisition phase. The system shall be designed to start positioner motion at an optimum time after acquisition is complete. An example would be to send a move command to a positioner some number of system milliseconds (i.e. t > MinMeasTime) after muzzle exit to assure a velocimeter has collected its Doppler data.

5.5. **Data Employment.** Data employment functions and features are intended to allow YTC and its test clients and sponsors to manipulate, modify, view, analyze, print, summarize, and convert the acquired source data into engineering and importable data products for further evaluation and reporting. All data employment functions, with possible exceptions of quick look and summary generation, shall be usable by YTC and others on any standard MicroSoft XP and Office-equipped PC after the data is posted to a central archive. Data employment applies primarily to digitized data from the analog channels. Employment shall provide display, graphing, filing, conversion, utility, analytic, and summarization functions. Detailed requirements are outlined below. (Note: Velocimeter data is not included. It is employed directly by the velocimeters. Chronography data employment is also excluded because it is less complex and is readily combined directly with chronography data acquisition and manipulation with Excel as outlined in a separate section.)

5.5.1. Data Display. Data display functions shall present important administrative, statistical, and graphic information for one or multiple opened data channels. The data display shall also provide access to and is supported by filing and analysis functions described separately. Display functions shall perform in at least two modes. The two modes are presented below. YTC encourages a third mode that would be available during channel setup for viewing parameter change affects.

5.5.1.1. Quick Look Mode. The system shall provide user-selected channels rapidly displayed between rounds in near real time to verify basic health of the channel path from the last round. Each channel display shall include the channel name, key indicators and statistics such as limit, spike, and over range detected, peak value, and a waveform with axes. The displays shall automatically size themselves and refresh with new data. The user shall have controls to at least select the number of displays presented on the screen at one time, the number of seconds (nn.d) between new screens, stop/start, back and forward by screen.

5.5.1.2. Data Production Mode. The system shall provide a user-configurable display of opened data channels. The purpose of the data production display is to allow a YTC user or client to present and examine the data during its manipulation, and save, convert, and print the manipulated results. The display shall include menu selections, text, indicators, controls, cursors, waveform graph(s), and legend.

a. Text and Indicators: These elements shall be grouped by purpose and/or type allowing the user to readily focus on and understand all key aspects of the selected data. Key data text and indicator contents include, but are not limited to: Classification, Date, UTC, Round No., Channel, Project/Item, Test Director, and Test Location Names, Filter Type, Cutoff Frequency, Sampling Rate, Min/Max Levels, Rise Time, Pulse Width, T4 Duration, Smoothing Parameters, Over Range, Spike, Acceptance Limits, Corrected Gage Factor, and start and ending cursor readings for amplitudes, x-axis times (abscissas), and their differences.
b. Controls: Menu selections and controls, options, and settings for data

saving, conversion, printing, application of corrected gage factor, and utilities and analysis functions. Display and analysis settings shall be retained, saved, and recalled, until changed, for repeated evaluations of new data channels.

c. Waveform Graphs: Provide up to four user-controlled graph windows on the display for multiple waveforms in each window. X-axis (time) shall be selectable as referenced to time zero, time of day, or sample number. Provide zoom, pan, axes, grid, labeling, color, line types, marker types, cursors, and other controls and menu selections for comprehensive control of graph attributes.

d. Legend: Provide a user-controlled legend. Controls include but are not limited to show/hide, labels, and attribute meanings.

5.5.2. Data Opening and Filing. The system shall provide at least the following filing functions to support source data usage and the products derived from data display. These functions are intended to be accessed as a part of the data display.

a. Source Data Opening: Support rapid, between-round, quick-look data viewing during a mission. Open methods shall include all channels, all channels of one type (grouped), all channels of one card module, all channels from one round, and any combination of individual channels from the mission. Source data opens for display and manipulation into finished data products, or for view-only (including copy and print) of header data.

b. Data Product Opening: Same open methods as for source data. Data products open for modification and generation of additional data products.

c. Save and SaveAs: Save selected displayed data channels derived from analysis functions. Save mission Excel data summary workbook.

d. Export: Export displayed data products to other data files including ASCII with key header data, and graphics including jpeg and bitmap.

e. Print: Print/plot displayed data products and header data.

f. Overwrite: Source data shall not be overwritten except to annotate a correction to a mis-entered standard type, single value, gage factor. Gage factor correction shall be in a dedicated correction field of the source data header.

5.5.3. Data Utilities and Analyses. The system shall provide user-controlled utility and analysis functions to display, correct, or mitigate unexpected data problems and produce desired finished data products. These functions are intended to be accessed as a part of the data display.

5.5.3.1 Utilities. Data utilities shall include the following. Any data utility applied shall also leave a permanent annotation in the data file to identify the utility and any of its parameters.

a. Gage Factor: Provide a menu or control item to change an incorrect standard type, single value, gage factor. Gage factor correction shall be in a dedicated correction field of the source data header for the data display to recognize and use to produce subsequently corrected data.

b. Spike Detection: Provide user-controlled utility(s) to identify, warn, and remove, and smooth data products derived from source data containing signal spikes.

c. Normalization: Provide a user-controlled utility or algorithm to recognize an offset bias prior to transducer stimulation and amplitude-shift the data an equal amount back to compensate for the offset.

d. Inversion: Provide a user-controlled utility to invert (multiply by -1) any desired data channels.

5.5.3.2 Analysis. The following analytic functions shall be provided. Desired functions are included. Additional specialized analyses or algorithms are anticipated in future upgrades and are shown for information only.

a. Math: Provide user-controlled inter-channel algebra functions to calculate waveform sum, difference, product, and quotient based on the desired math relationship. In the special case where Breech and Chamber channel types are in use, the system shall automatically prompt the user to ask if differential pressure is desired. If yes, the differential data shall be calculated as breech pressure minus chamber pressure. Provide user-selectable channel multiplication factors to convert between pressure units (kPa, bar, psi) and to provide a generic multiplication factor for other conversions. YTC also desires finite single and double integral, and derivative functions.

b. Statistics: Provide user-controlled selection of displayed annotations for data statistics including number of samples, minimum and maximum peak values and abscissas, time zero (T0), ignition delay (t2), rise time (t5), pulse width, and action time (t4).

c. Smoothing; Provide user-controlled boxcar (sliding average) smoothing including numbers of points and passes. YTC desires additional user-controlled smoothing routines such as binomial (Gaussian) and polynomial (Savitzky-Golay).

d. Frequency: YTC desires analyses such as FFT, FHT, their inverses, waterfall, and JTFA.

e. Filtering: FUTURE OPTION - NOT PART OF SCOPE. User-controlled options for digital filtering using various filter types and methods. Candidates include low pass, high pass, band pass, band stop; Bessel, Butterworth, Chebyshev, Inverse Chebyshev, and Elliptical.

f. Combined Strain: FUTURE OPTION - NOT PART OF SCOPE. User-controlled entry of Young's modulus and Poisson's ratio by channel with system calculation of principal strains, stresses, and angle for strain rosettes (rectangular, delta, and T) data.

g. SRS: FUTURE OPTION - NOT PART OF SCOPE. User-controlled shock response spectrum (Smallwood SRS algorithm) including:
Frequency Resolution - 1/N octave (1/12th default)
Damping Ratio
Results Format Types-
1 -- positive primary
2 -- negative primary
3 -- absolute maximum primary
4 -- positive residual
5 -- negative residual
6 -- absolute maximum residual
7 -- largest of 1&4, maximum positive
8 -- largest of 2&5, maximum negative
9 -- maximax, the largest absolute value of 1-8
10 -- returns 1&2 graphed together
11 -- returns a matrix (9,length(fn)) with all the types, 1-9

h. BOP: FUTURE OPTION - NOT PART OF SCOPE. User-controlled application of GFI blast over pressure algorithms with near real time validity checking for exposures to noise and blast impulses in air.

5.5.4. Data Summary. After the first round of a mission, the system shall open a new Excel data summary workbook. Note, the first round includes any check or dry fires, warmer and spotter rounds. The workbook shall be updated on a near real time basis with summary statistics for each round after it is fired. The workbook shall provide a worksheet for each type of data group such as Breech and Chamber Pressures, Generic Pressures, Displacements and Voltages, Accelerometers, Strains, Forces, Microphones, Trigger and Time Zero and Muzzle Exit, and Other. Multiple sheets acceptable for a large data group. The data summary workbook shall accommodate addition or removal of channels and shall allow rapid user selection of round type (Dry fire, Spotter, Warmer, Calibration, or Test) and entry of remarks. Appendix C presents the statistics required for two channel group types and an example of a Breech and Chamber summary sheet.

5.6. **Shutdown.** System and power shutdown shall be orderly and without data loss. The shut down sequence shall as automatic as possible and shall notify the technician to complete or exit any critical ongoing functions, save any critical data records and log entries, warn of any faults, reset hardware, and halt any other functions as needed.

6. **DOCUMENTATION** You shall provide complete documentation via reproducible CDROM for the hardware components and software application.

6.1. **Hardware.** Hardware documentation shall include complete OEM operation and service manuals, parts lists and schematics. Manual(s) shall include instructions and sequence for system start up, settings, operation, calibration, troubleshooting, and figure(s) showing cabling connections to signal inputs and between all components.

6.2. **Software.** Software documentation shall include a complete user's manual and imbedded help for system calibration, setup, operation, data manipulation, and troubleshooting. A user's quick reference guide shall be provided. Documentation shall also include the installable application and all source code and associated auxiliary files, settings, options, and procedures used to compile/assemble, link, build, and install the final production version of the executable application. Source code and all associate files shall include embedded documentation of variables, functions, libraries and routines.

7. **TRAINING** You shall provide on-site training at YTC for four (4) personnel. The goal of this training will be to familiarize senior personnel with the system hardware and application so they can in turn train the field technicians/users. Training shall consist of at least high to mid-level system design, functions, behaviors, and detailed procedures for setup, calibration, checkout, operation, diagnostics, recovery, and shutdown.

8. **REFERENCES**

8.1. Weibel W-700 Velocity Analyzer User's Guide.
8.2. Infinition TestCenter User Guide
8.3. Standard Operating Procedure for Muzzle Velocity Radar Systems.
8.4. ITS 6115G-TSM Technical Description.

9. **GFE** YTC will provide the following Government furnished property within a reasonable time after contract award.

9.1. Velocimeters.

9.1.1. Weibel W-700, RemDopp, two antennas, and accessories.

9.1.2. Infinition JB-5000, TestCenter software, two antennas, and accessories.

9.2. Timing & Chronography.

a. ITS 6115G-TSM, power cord, and manual.
b. Fuze chronography LED/SCU and IRD and power supply.

10. **SHIPPING** Shipping shall be provided as follows.

10.1. **Government.** YTC will provide shipping to deliver all GFE to the contractor.

10.2. **Contractor.** The contractor shall provide shipping to return all GFE and deliver purchased products to YPG.

11. **DELIVERIES** Deliveries shall consist of design submittals, engineering products, a system demonstration(s), and hardware line items.

11.1. **Submittals.** An early key milestone shall certify system expectation to fully succeed using the GFE. Additional preliminary and interim reviews shall be proposed and executed as you consider necessary. Early in design, you shall provide a block diagram and functional flowchart or outline indicating overall system design approach and features. These submittals are considered part of the engineering costs.

11.2 **Products.** YTC recommends production deliveries structured as follows.

a. First Article System: Intermediate class (32 chan) system including engineering, eight (8) signal conditioning channels configured as four (4) channels each of charge/IEPE, and bridge/voltage, eight (8) digitizer channels, complete calibration subsystem, sequencing, system PC, communications interface(s), two (2) positioners, UPS, rack(s) with minimum 18 H inches open rack space, and GFE TSMU installed, cabling, patch panels, and accessories connected. GFE velocimeter unmounted in a drawer (readily removable), and second GFE velocimeter and other items packed as originally shipped or equal.
b. Basic System: Basic class (8 chan) system including 4 signal conditioning channels configured as four channels of charge and IEPE, 4 digitizer channels, complete calibration subsystem, sequencing, system PC, communications interface(s), UPS, rack with open space for TSMU plus additional minimum open 18 H inches, velocimeter drawer, cabling, patch panels, and accessories installed & connected.
c. Intermediate System: Intermediate class (32 chan) system including 16 signal conditioning channels configured as eight (8) channels of charge/IEPE and eight (8) of bridge/voltage, 16 digitizer channels, complete calibration subsystem, sequencing, system PC, communications interface(s), UPS, rack(s) with open space for TSMU plus additional minimum open 18 H inches, velocimeter drawer, cabling, patch panels, and accessories installed & connected.
d. Large System: Large class (128 chan) system including 32 signal conditioning channels configured as eight (8) channels of charge/IEPE and 24 of bridge and voltage, 32 digitizer channels, complete calibration subsystem, sequencing, system PC, communications interface(s), UPS, rack(s) with open space for TSMU plus additional minimum open 18 H inches, velocimeter drawer, cabling, patch panels, and accessories installed & connected.

e. xxxDopp: Fully functional replacement for obsolete, DOS-based RemDopp software.
f. Positioner: Additional positioners priced each and in lots.
g. Conditioner, IEPE: Additional charge and IEPE signal conditioners priced each and in lots.
h. Conditioner, Bridge: Additional bridge and voltage signal conditioners priced each and in lots.
i. Digitizer: Additional digitizers priced each and in lots.
j. Training: Training at YTC after final acceptance and orientation period.
k. Upgrade Options: Activation of optional upgrade functions priced each and in a package(s).
l. Upgrade Labor: Engagement of engineering and technical support for modifications and upgrades.
m. Other Hardware or Support Considered Prudent: As recommended / adopted.

## Appendix A.  Performance Verifications*

### The Use of Test-Modes for Measurement System Verification/Validation

The Precision Filters signal conditioning equipment has many special hardware features that may be utilized for system verification and validation.  The Test-Modes setup the system in order to perform specific verifications on the measurement system hardware and connected transducers and cables that otherwise would be difficult (time consuming) or impossible to do. The Test-Modes will have a substantial impact on system life cycle costs by making time-consuming manual verification and validation routines automated.  The user of the measurement system will be able to provide the customer with documented proof that the measurement system is within specification and that the noise levels are under control.

Rapid and powerful measurement system diagnostic capabilities can be provided by the utilization of the Test-Modes along with the measurement capability of the data acquisition system. Limits may be set in the acquisition computer to flag any out of tolerance channel.

A description of available Test-Modes for the various signal conditioner cards are as follows:

| 27104A/28104/28134 Bridge Conditioner Test-Modes | | |
|---|---|---|
| Test-Mode | Description | Purpose |
| RUN | This is the operate mode for a channel. All channel parameters are under program control. | When the channel is returned to RUN from any Test-Mode, the previously set parameters are restored. |
| Test Bus | A switch at the amplifier input disconnects the sensor and substitutes the signal on the Test Bus. The Test Bus is an analog bus in the 28000 system that is common to all channel inputs. An external calibration signal can be applied via a BNC connector at the chassis front panel. | Inject calibration signals to channel inputs for purposes of verifying measurement system performance. |
| Amplifier Short | A switch disconnects the input from the transducer and shorts the input to ground. | Verify/document signal conditioner and digitizer noise levels. |
| Excitation Off | Sets the excitation voltage to zero | Verify that transducer self generated noise levels and noise pickup in the cables is sufficiently low. |
| Excitation Monitor | Connect the excitation supply across the differential amplifier input.<br>The channel is DC coupled. The excitation voltage is measured by connecting the input amplifier through a precision resistor divider with a gain of x1/2. The input amplifier is set to a gain of Fsout/10V. Note: Gain of x1/2 is used because the excitation voltage can be programmed to levels that exceed that amplifier input range. | Verify excitation voltage through the amplifier. |
| Shunt Calibration | Precision bipolar voltage is inserted via precision resistors that are connected to the bridge corners. 4096 steps of shunt calibration are provided. Single shunt of any bridge arm or double shunt of opposing arms is supported. | Verify resistance of all bridge arms. Verify system DC span and linearity. |
| Output Monitor | The monitor bus is an analog bus available in the 28000 chassis and is used to view channel outputs. A switch at the output of each channel allows for a multiplexed connection to the monitor bus. Note: The normal signal path is not interrupted by the monitor function. | View analog output levels prior to the digitizer. |

| **28454 Dynamic Strain Conditioner Test-Modes** | | |
|---|---|---|
| Test-Mode | Description | Purpose |
| RUN | This is the operate mode for a channel. All channel parameters are under program control. | When the channel is returned to RUN from any Test-Mode, the previously set parameters are restored. |
| Test Bus | A switch at the amplifier input disconnects the sensor and substitutes the signal on the Test Bus. The Test Bus is an analog bus in the 28000 system that is common to all channel inputs. An external calibration signal can be applied via a BNC connector at the chassis front panel. | Inject calibration signals to channel inputs for purposes of verifying measurement system performance. |
| Amplifier Short | A switch disconnects the input from the transducer and shorts the input to ground. | Verify/document signal conditioner and digitizer noise levels. |
| Excitation Off | Set the excitation current to zero | Verify that transducer self generated noise levels and noise pickup in the cables is sufficiently low. |
| IDRIVE | Connect the differential amplifier input across a precision 100 Ohm 0.01% 1ppm resistor on the DRIVE side current loop.<br>The channel is DC coupled. | Verify DRIVE excitation current with the transducer connected through the amplifier. Data acquisition system can record all dynamic strain excitation currents simultaneously. |
| ISINK | Connect the differential amplifier input across a precision 100 Ohm 0.01% 1ppm resistor on the SINK side current loop.<br>The channel is DC coupled. | Verify SINK excitation current with the transducer connected through the amplifier. Data acquisition system can record all dynamic strain excitation currents simultaneously. |
| Loop Resistance | The excitation current is programmed to 1mA. The amplifier is DC coupled. The channel gain is set to 1. | Verify transducer + cable resistance. Loop-Resistance verification can be run prior to a test, during a test or after the test. |
| AC Dither | An AC current is summed with the DC excitation current to simulate an AC stimulus through the transducer. The reference to the AC current is provided by the signal on the Test Bus. 100uA of current is supplied per V on Test Bus. | Verify end to end frequency response of measurement system, including cables. Verify system span. |
| Output Monitor | The monitor bus is an analog bus available in the 28000 chassis and is used to view channel outputs. A switch at the output of each channel allows for a multiplexed connection | View analog output levels prior to the digitizer. |

| | | |
|---|---|---|
| | to the monitor bus. Note: The normal signal path is not interrupted by the monitor function. | |

| 27334 Dual Mode Charge/IEPE Conditioner Test-Modes | | |
|---|---|---|
| Test-Mode | Description | Purpose |
| RUN | This is the operate mode for a channel. All channel parameters are under program control. | When the channel is returned to RUN from any Test-Mode, the previously set parameters are restored. |
| Test Bus | A switch at the amplifier input disconnects the sensor and substitutes the signal on the Test Bus. The Test Bus is an analog bus in the 28000 system that is common to all channel inputs. An external calibration signal can be applied via a BNC connector at the chassis front panel. | Inject calibration signals to channel inputs for purposes of verifying system performance. |
| Amplifier Short | A switch disconnects the input from the charge converter (charge mode) or the IEPE transducer (IEPE mode) and shorts it to ground. | Verify/document signal conditioner and digitizer noise levels. |
| Excitation Off (IEPE Mode Only) | Set the IEPE Current to zero | Verify that transducer self generated noise levels and noise pickup in the cables is sufficiently low in IEPE mode. |
| AC Current | Modulate the IEPE current with the signal on the test bus. AC current level is 100uA per volt on the test bus | Verify transducer cabling and output impedance. Signal generated as if it comes from the transducer itself. |
| Shunt Calibration (Charge Mode Only) | A test signal is inserted to the charge converter input through a precise capacitor. | Verify charge converter gain. |
| Output Monitor | The monitor bus is an analog bus available in the 28000 chassis and is used to view channel outputs. A switch at the output of each channel allows for a multiplexed connection to the monitor bus. Note: The normal signal path is not interrupted by the monitor function. | View analog output levels prior to the digitizer. |

## Suggested Verification/Validation Tests to be Performed Prior to Running the Actual Test

**For 27104A/28104/28134:**

1. Excitation Check: Set the amplifier to Test-Mode “EXC” and record the DC excitation voltage on each channel. The measured excitation voltage shall be compared to Yuma specified limits for pass/fail criteria.
2. AC Gain/Bandwidth Check: Set Test-Mode to “Testbus”. Apply signal to the testbus input at the programmed cutoff frequency of the filter and measure the AC gain at the channel output. Channels with programmed gains that are within 40dB of each other can be evaluated with the same calibration signal level. Channels should be tested in groups according to the programmed gain level. The measured gain shall be compared to Yuma specified limits for pass/fail criteria.
3. DC Gain Check: Set Test-Mode to “Testbus”. Apply DC signal to testbus and measure the DC gain of the channels. Channels with programmed gains that are within 40dB of each other can be evaluated with the same calibration signal level. Channels should be tested in groups according to the programmed gain level. The measured gain shall be compared to Yuma specified limits for pass/fail criteria.
4. Shunt Calibration Check: Set up conditioner for single shunt of R1 at user specified level. Set Test-Mode to “SHUNT”. Measure DC voltage at the output and compare to Yuma specified limits. Repeat procedure for R2, R3 and R4.
5. DC Offset Check: Set Test-Mode to “Short”. Measure DC offset at channel output. The measured offset shall be compared to Yuma specified limits for pass/fail criteria.
6. DC Zero Check (after auto-balance w/ transducer connected): Set Test-Mode to “RUN”. Measure DC offset at channel output. The measured offset shall be compared to Yuma specified limits for pass/fail criteria.
7. Noise Check Input Short: Set Test-Mode to “Short”. Measure AC rms noise at channel output. The measured noise shall be compared to Yuma specified limits for pass/fail criteria.
8. Noise Check Excitation Off: Set Test-Mode to “EXC Off”. Measure AC rms noise at channel output. The measured noise shall be compared to Yuma specified limits for pass/fail criteria.

**For 28454:**

1. Excitation Check: Set the amplifier to Test-Mode “IDRIVE” and record the DC excitation current on each channel. The measured excitation voltage shall be compared to Yuma specified limits for pass/fail criteria.
2. Excitation Check: Set the amplifier to Test-Mode “ISINK” and record the DC excitation current on each channel. The measured excitation voltage shall be compared to Yuma specified limits for pass/fail criteria.
3. AC Gain/Bandwidth Check: Set Test-Mode to “Test bus”. Apply signal to the test bus input at the programmed cutoff frequency of the filter and measure the AC gain at the channel output. Channels with programmed gains that are within 40dB of each other can be evaluated with the same calibration signal level. Channels should be tested in groups according to the programmed gain level. The measured gain shall be compared to Yuma specified limits for pass/fail criteria.
4. Loop Resistance Check (w/ transducer connected): Set Test-Mode to “Loop Resistance”. Measure DC voltage at the channel output. Loop resistance = 1 Ohm per mVdc. The measured loop resistance shall be compared to Yuma specified limits for pass/fail criteria.
5. AC Calibration Check/Cable & Transducer Check: Set Test-Mode to “AC Current”. Apply signal to the Test Bus input at the programmed cutoff frequency of the filter and measure the AC gain at the channel output. AC current level is 100uA/V of test bus signal. Channels with programmed gains that are within 40dB of each other can be evaluated with the same calibration signal level. Channels should be tested in groups according to the programmed gain level. The measured gain shall be compared to Yuma specified limits for pass/fail criteria.
6. DC Zero Check (w/ transducer connected): Set Test-Mode to “RUN”. Measure DC offset at channel output. The measured offset shall be compared to Yuma specified limits for pass/fail criteria.
7. Noise Check Input Short: Set Test-Mode to “Short”. Measure AC rms noise at channel output. The measured noise shall be compared to Yuma specified limits for pass/fail criteria.

8. Noise Check Excitation Off: Set Test-Mode to “EXC Off”. Measure AC rms noise at channel output. The measured noise shall be compared to Yuma specified limits for pass/fail criteria.

**For 28334 IEPE Mode:**

1. AC Gain/Bandwidth Check: Set Test-Mode to “Test bus”. Apply signal to the test bus input at the programmed cutoff frequency of the filter and measure the AC gain at the channel output. Channels with programmed gains that are within 40dB of each other can be evaluated with the same calibration signal level. Channels should be tested in groups according to the programmed gain level. The measured gain shall be compared to Yuma specified limits for pass/fail criteria.
2. AC Current: Set Test-Mode to “AC Current”. Apply test bus signal at frequency of 0.1 times the programmed cutoff frequency. Measure signal at channel output and compute transducer + cable impedance (Z = (10E3/GAIN)*(Vout/Vin)
3. DC Offset Check: Set Test-Mode to “Short”. Measure DC offset at channel output. The measured offset shall be compared to Yuma specified limits for pass/fail criteria.
4. Noise Check Input Short: Set Test-Mode to “Short”. Measure AC rms noise at channel output. The measured noise shall be compared to Yuma specified limits for pass/fail criteria.
5. Noise Check Excitation Off: Set Test-Mode to “EXC Off”. Measure AC rms noise at channel output. The measured noise shall be compared to Yuma specified limits for pass/fail criteria.

**For 28334 Charge Mode:**

1. AC Gain/Bandwidth Check: Set Test-Mode to “Shunt cal”. Apply signal to the test bus input at the programmed cutoff frequency of the filter and measure the AC gain at the channel output. Channels with programmed gains that are within 40dB of each other can be evaluated with the same calibration signal level. Channels should be tested in groups according to the programmed gain level. The measured gain shall be compared to Yuma specified limits for pass/fail criteria.
2. DC Offset Check: Set Test-Mode to “Run”. Measure DC offset at channel output. The measured offset shall be compared to Yuma specified limits for pass/fail criteria.
3. Noise Check Input Short: Set Test-Mode to “Short”. Measure AC rms noise at channel output. The measured noise shall be compared to Yuma specified limits for pass/fail criteria.
4. Noise Check Run Mode: Set Test-Mode to “Run”. Measure AC rms noise at channel output. The measured noise shall be compared to Yuma specified limits for pass/fail criteria.

**Programmable Features for the 27104A/28104/28134 that shall be controlled by user interface via Ethernet on 28000 Backplane Interface Card:**

Excitation Level
Excitation Sense
Autobalance
Input Coupling
Cutoff Frequency
Filter Bypass
Shunt Calibration Setup
Input Shield
Bridge Resistor Readback
Bridge Configuration Readback
Channel Gain Setup “Wizard”:
    Fsr = Fullscale Input (Range) in MU
    Sensor = Sensor Sensitivity in mV/V/MU
    Reserve = Outband Reserve (Sets gain distribution around filter)
    Fsout = Fullscale output, in volts.
Test-Mode (Run, Exc, Zero Exc, Short, Test Bus)

**Programmable Features for the 28454 that shall be controlled by user interface via Ethernet on 28000 Backplane Interface Card:**

Excitation Level

Excitation Sense
Suppress
Input Coupling
Cutoff Frequency
Filter Bypass
2-wire/4-wire input setup
Input Shield
Channel Gain Setup “Wizard”:
    Fsr = Fullscale Input (Range) in MU
    Sensor = Sensor Sensitivity in mV/mA/MU
    Reserve = Outband Reserve (Sets gain distribution around filter)
    Fsout = Fullscale output, in volts.
Test-Mode (Run, AC Current, IDRIVE, ISINK, IZERO, Short, Test Bus, Loop Resistance)

**Programmable Features for the 28334 that shall be controlled by user interface via Ethernet on 28000 Backplane Interface Card:**

IEPE Mode:
- IEPE Current Level
- Cutoff Frequency
- Filter Bypass
- Input Shield
- Channel Gain Setup “Wizard”:
    - Fsr = Fullscale Input (Range) in MU
    - Sensor = Sensor Sensitivity in mV/MU
    - Reserve = Outband Reserve (Sets gain distribution around filter)
    - Fsout = Fullscale output, in volts.
- Test-Mode (Run, AC Current, IZERO, Short, Test Bus)

Charge Mode:
- Cutoff Frequency
- Filter Bypass
- Input Shield
- Charge Reset
- Time Constant (Short/Long)
- Channel Gain Setup “Wizard”:
    - Fsr = Fullscale Input (Range) in MU
    - Sensor = Sensor Sensitivity in pC/MU
    - Reserve = Outband Reserve (Sets gain distribution around filter)
    - Fsout = Fullscale output, in volts.
- Test-Mode (Run, Shunt Cal, Short, Test Bus)

**System Features:**
- Monitor Bus Channel
- 28000-System Status
    - Report power supply voltages
    - Report internal temperature sensor readings
    - Report cooling fan status information
- Overload Log
    - Clear overload/fault log file immediately prior to test.
    - Read and save overload/fault log file with the test data.
- Calibration (May want password access to this since only required once/yr.)
    - Gain Adjust
    - Excitation Adjust
    - Offset Adjust

## Appendix B. Notional Calibration Sheet

CALIBRATION REPORT
for
PRESSURE TRANSDUCER

Manufacturer: YPG

Model No: E30HPE        Serial No: 102

Owner: YPG

Date of Calibration: 1400 10/15/2001

Calibration Technician: EWM

Remarks: NONE

Calibration capacitor= 10000 picofarads    Temperature = 79

| DATAPOINT NUMBER | PRESSURE (psig) | TRANSDUCER OUTPUT (pcb) | BEST FIT DEVIATION (%ind, | %fs) |
|---|---|---|---|---|
| 1 | 19844 | 6199 | -1.95 | -0.32 |
| 2 | 19848 | 6206 | -1.85 | -0.31 |
| 3 | 29785 | 9420 | -0.72 | -0.18 |
| 4 | 29788 | 9423 | -0.71 | -0.18 |
| 5 | 39720 | 12600 | -0.42 | -0.14 |
| 6 | 39716 | 12620 | -0.25 | -0.09 |
| 7 | 49641 | 15793 | -0.14 | -0.06 |
| 8 | 49630 | 15805 | -0.04 | -0.02 |
| 9 | 59548 | 18985 | 0.08 | 0.04 |
| 10 | 59546 | 18997 | 0.14 | 0.07 |
| 11 | 69465 | 22158 | 0.12 | 0.07 |
| 12 | 69468 | 22170 | 0.18 | 0.10 |
| 13 | 79378 | 25343 | 0.21 | 0.14 |
| 14 | 79869 | 25333 | 0.19 | 0.13 |
| 15 | 89308 | 28503 | 0.18 | 0.13 |
| 16 | 89292 | 28501 | 0.18 | 0.14 |
| 17 | 99187 | 31642 | 0.13 | 0.11 |
| 18 | 99185 | 31610 | 0.04 | 0.03 |
| 19 | 109128 | 34792 | 0.08 | 0.07 |
| 20 | 109132 | 34773 | 0.02 | 0.01 |
| 21 | 119031 | 37855 | -0.17 | -0.17 |
| 22 | 119027 | 37818 | -0.27 | -0.27 |

Y-Intercept:     0 psi
Gage Coefficient:  3.1389 psi/picocoulomb

## Appendix C. Mission Data Summary Sheet

### 1. STATISTICS - BREECH AND CHAMBER PRESSURES.

| description* | units |
|---|---|
| Round# (nnnnn) | n/a |
| T0 (hh:mm:ss.ffffff, time of day) | UTC |
| Round Class (by user, (D)ryfire, (C)alibrator, (S)potter, (W)armer, (T)est) | n/a |
| T4PriTime (nnnn.ddd, primary t4, pri LED) | ms |
| T4SecTime (nnnn.ddd, secondary t4, 2nd LED, mic, or ion switch) | ms |
| PriLedMax (nn.dddd, primary LED positive peak) | Volts |
| PriLedMin (nn.dddd, primary LED negative peak) | Volts |
| PriLed50Time (nnnn.ddd, period from T0 to 50% of PriLedMax, verif. t4) | ms |
| PriLedMinTime (nnnn.ddd, period from T0 to PriLedMin) | ms |
| FireCurMax (nn.ddd, firing voltage positive peak) | Amps |
| BreechMax (nnnnn, maximum breech pressure) | Bar |
| BreechMin (nnnnn, minimum breech pressure) | Bar |
| BreechMaxTime (nnnn.ddd, period from T0 to BreechMax) | ms |
| BreechMinTime (nnnn.ddd, period from T0 to BreechMin) | ms |
| BreechIgnDelay (nnnn.ddd, breech gage ignition delay, t2, T0 to 10% peak) | ms |
| Breech90Time (nnnn.ddd, breech gage T0 to 90% of peak) | ms |
| BreechRiseTime (nnnn.ddd, breech gage rise time, t5, 10% to 90% peak) | ms |
| BreechF30Time (nnnn.ddd, breech gage falling/post-peak , T0 to 30% peak | ms |
| BreechF10Time (nnnn.ddd, breech gage falling/post-peak , T0 to 10% peak | ms |
| ChamMax (nnnnn, maximum chamber pressure) | Bar |
| ChamMin (nnnnn, minimum chamber pressure) | Bar |
| ChamMaxTime (nnnn.ddd, period from T0 to ChamMax) | ms |
| ChamMinTime (nnnn.ddd, period from T0 to ChamMin) | ms |
| ChamIgnDelay (nnnn.ddd, chamber gage ignition delay, t2, T0 to 10% peak) | ms |
| Cham90Time (nnnn.ddd, chamber gage T0 to 90% of peak) | ms |
| ChamRiseTime (nnnn.ddd, chamber gage rise time, t5, 10% to 90% peak) | ms |
| ChamF30Time (nnnn.ddd, chamber gage falling post-peak , T0 to 30% peak | ms |
| ChamF10Time (nnnn.ddd, chamber gage falling/post-peak , T0 to 10% peak | ms |
| DifMax (nnnnn, calc'd waveform difference Breech - Chamber, positive peak) | Bar |
| DifMaxTime (nnnn.dd, period from T0 to DifMax) | ms |
| DifMinBP (nnnnn, calc'd waveform difference Breech - Chamber, negative peak, occurring before breech pressure BreechMaxTime | Bar |
| DifMinBPTime (nnnn.ddd, period from T0 to DifMinBP) | ms |
| DifMin (nnnnn, calc'd waveform difference Breech - Chamber, negative peak) | Bar |
| DifMinTime (nnnn.ddd, period from T0 to DifMin) | ms |

Note: * Notation Example:

"ddd" denotes at least 3 decimal places typically needed.
"hh:mm:ss.ffffff", time of day including fraction of a second
"nnn" denotes at least 3 integer places typically needed.
"YY/MM/DD" calendar date

1. **STATISTICS - REST OF CHANNEL GROUP TYPES.**

| description* | units |
|---|---|
| Round# (nnnnn) | n/a |
| T0 (hh:mm:ss.ffffff, time of day) | UTC |
| Round Class (by user, (D)ryfire, (C)alibrator, (S)potter, (W)armer, (T)est) | n/a |
| T4PriTime (nnnn.ddd, primary t4, pri LED) | ms |
| Ch001Max (nnnnn, maximum Ch001 ordinate, in EU setting) | EU |
| Ch001Min (nnnnn, minimum Ch001 ordinate, in EU setting) | EU |
| Ch001MaxTime (nnnn.ddd, period from T0 to Ch001Max) | ms |
| Ch001MinTime (nnnn.ddd, period from T0 to Ch001Min) | ms |
| Ch002Max (nnnnn, maximum Ch002 ordinate, in EU setting) | EU |
| Ch002Min (nnnnn, minimum Ch002 ordinate, in EU setting) | EU |
| Ch002MaxTime (nnnn.ddd, period from T0 to Ch002Max) | ms |
| Ch002MinTime (nnnn.ddd, period from T0 to Ch002Min) | ms |
| o | |
| o | |
| o | |
| o | |
| ChNNNMax (nnnnn, maximum ChNNN ordinate, in EU setting) | EU |
| ChNNNMin (nnnnn, minimum ChNNN ordinate, in EU setting) | EU |
| ChNNNMaxTime (nnnn.ddd, period from T0 to ChNNNMax) | ms |
| ChNNNMinTime (nnnn.ddd, period from T0 to ChNNNMin) | ms |

Note: * Notation Example:
"ddd" denotes at least 3 decimal places typically needed.
"hh:mm:ss.ffffff", time of day including fraction of a second
"nnn" denotes at least 3 integer places typically needed.
"NNN" integer channel number from 1 to N
"YY/MM/DD" calendar date

| ROUND# | T.O.D. | RND CLASS | T4 Prim TIME | T4 Secnd TIME | T4 PRI POS. PE | T4 PRI NEG. PE | T4 PRI TIME OF PE | T4 PRI TIME OF NEG PEAK | FIRING CURRENT POS. PEA | BREECH POS. PE | BREECH NEG. PE | BREECH TIME OF PEAK | BREECH TIME OF NEG PEAK | BREECH ING. DEL | BREECH RISE TIM | BREECH TIME AT 90% BF PE | BREECH TIME AT 30% AF PE | BREECH TIME AT 10% AF PE | CHAMBER POS. P | CHAMBER NEG. P | CHAMBER TIME OF PEAK | CHAMBER TIME OF NEG PE | CHAMBER ING. DELAY | CHAMBER RISE T | CHAMBER TIME AT 90% BF | CHAMBER TIME / CHAM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | UTC | TXT | mS | mS | lts | 488 | mS. | mS. | mps | BAR | BAR | mS. | mS. | mS. | mS. | mS. | mS. | mS. | BAR | BAR | mS. | mS. | mS. | mS. | mS. | mS. |
| 800 | 2005/02/16 14:32:53.085743 | T | 5430.24 | 5445.49 | 0 | -0.00488 | 0 | 23 | 5.173 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 801 | 2005/02/16 14:35:34.893073 | S | 3798.44 | 3796.8 | 0 | -0.00488 | 0 | 9 | 2.245 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 800 | 2005/02/16 14:38:56.087128 | S | 5442.24 | 14.977 | 0.00488 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 801 | 2005/02/16 14:42:10.123600 | S | 15.322 | 15.468 | 4.9776 | 0 | 16 | 1 | 8.979 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 802 | 2005/02/16 14:45:58.569383 | S | 15.687 | 15.837 | 4.9776 | 0 | 16 | 1 | 9.174 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 803 | 2005/02/16 14:48:38.595495 | S | 14.965 | 15.1 | 4.9776 | 0 | 19 | 0 | 9.565 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 804 | 2005/02/16 14:51:56.715038 | S | 15.299 | 15.434 | 4.9776 | 0 | 15 | 0 | 9.174 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 805 | 2005/02/16 14:54:57.543580 | C | 15.108 | 15.241 | 4.9776 | 0 | 16 | 0 | 9.272 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 806 | 2005/02/16 14:58:48.138920 | S | 15.198 | 15.322 | 4.97272 | 0 | 15 | 0 | 9.272 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 807 | 2005/02/16 15:02:03.492000 | C | 15.825 | 15.96 | 4.9776 | 0 | 17 | 0 | 8.882 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 808 | 2005/02/16 15:05:03.950848 | C | 15.563 | 15.693 | 4.9776 | 0 | 17 | 1 | 9.76 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 809 | 2005/02/16 15:07:48.524258 | C | 15.141 | 15.272 | 4.9776 | 0 | 15 | 0 | 8.784 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 810 | 2005/02/16 15:11:43.349182 | T | 14.913 | 15.046 | 4.97272 | 0 | 15 | 0 | 9.174 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 811 | 2005/02/16 15:14:30.108455 | T | 14.997 | 15.144 | 4.97272 | -0.00488 | 15 | 0 | 9.174 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 812 | 2005/02/16 15:17:54.974941 | T | 15.845 | 15.983 | 4.97272 | 0 | 16 | 0 | 9.565 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 813 | 2005/02/16 15:21:21.287116 | T | 14.709 | 14.839 | 4.97272 | 0 | 15 | 0 | 9.174 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 814 | 2005/02/16 15:24:35.571640 | T | 16.534 | 16.659 | 4.9776 | 0 | 19 | 0 | 9.174 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 815 | 2005/02/16 15:27:33.412724 | T | 15.846 | 15.965 | 4.9776 | 0 | 18 | 0 | 8.882 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 816 | 2005/02/16 15:30:18.018043 | T | 14.698 | 14.821 | 4.97272 | 0 | 15 | 0 | 9.37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 817 | 2005/02/16 15:33:18.533531 | T | 15.259 | 15.387 | 4.97272 | 0 | 15 | 0 | 9.077 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 818 | 2005/02/16 15:36:20.326680 | T | 15.126 | 15.272 | 4.97272 | 0 | 15 | 0 | 9.37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 819 | 2005/02/16 15:39:13.921914 | T | 14.426 | 14.564 | 4.97272 | 0 | 14 | 0 | 9.37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 820 | 2005/02/16 16:19:34.688393 | S | 17.889 | 18.021 | 4.97272 | 0 | 18 | 0 | 9.37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 821 | 2005/02/16 16:22:12.446439 | S | 18.22 | 18.348 | 4.9776 | 0 | 20 | 0 | 9.37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 822 | 2005/02/16 16:25:02.013465 | S | 16.612 | 16.74 | 4.97272 | 0 | 17 | 0 | 9.37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 823 | 2005/02/16 16:28:44.566215 | C | 19.735 | 19.858 | 4.97272 | 0 | 20 | 0 | 9.077 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 824 | 2005/02/16 16:31:59.625940 | T | 18.984 | 19.116 | 4.97272 | 0 | 19 | 0 | 9.272 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 825 | 2005/02/16 16:34:56.469445 | C | 17.547 | 17.675 | 4.97272 | 0 | 18 | 0 | 9.37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 826 | 2005/02/16 16:37:34.545185 | T | 17.668 | 17.792 | 4.9776 | 0 | 21 | 0 | 9.077 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 827 | 2005/02/16 16:40:39.480535 | C | 19.222 | 19.343 | 4.97272 | 0 | 19 | 0 | 9.174 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 828 | 2005/02/16 16:44:14.317816 | C | 17.267 | 17.395 | 4.97272 | 0 | 17 | 0 | 9.174 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 829 | 2005/02/16 16:46:53.936474 | C | 18.098 | 18.227 | 4.9776 | 0 | 18 | 0 | 9.565 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 830 | 2005/02/16 16:49:56.927372 | T | 17.561 | 17.693 | 4.9776 | 0 | 18 | 0 | 8.979 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 831 | 2005/02/16 16:52:58.235080 | T | 18.385 | 18.516 | 4.97272 | 0 | 18 | 0 | 9.467 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 832 | 2005/02/16 16:56:28.066493 | T | 0 | 0 | 0.00488 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 999 | 2005/02/16 18:30:37.066272 | S | 0 | 0 | 0.00488 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1000 | 2005/02/16 18:33:21.448005 | S | 0 | 0 | 0 | 0 | 0 | 0 | 2.342 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1001 | 2005/02/16 18:37:11.711561 | S | 0 | 0 | 0.00488 | 0 | 0 | 0 | 2.245 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1002 | 2005/02/16 18:39:55.482690 | S | 0 | 0 | 0.00488 | 0 | 0 | 0 | 5.075 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 832 | 2005/02/16 18:43:21.195629 | S | 18.208 | 18.336 | 4.9776 | 0 | 18 | 0 | 9.174 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 833 | 2005/02/16 18:46:06.087260 | C | 21.07 | 21.202 | 4.9776 | 0 | 21 | 0 | 8.686 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 834 | 2005/02/16 18:49:28.539342 | T | 18.72 | 18.846 | 4.9776 | 0 | 19 | 0 | 9.174 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 835 | 2005/02/16 18:52:17.395920 | C | 18.037 | 18.161 | 4.9776 | 0 | 18 | 0 | 9.37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 836 | 2005/02/16 18:55:47.754830 | T | 16.985 | 17.118 | 4.9776 | 0 | 17 | 0 | 8.979 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 837 | 2005/02/16 18:58:29.365599 | T | 20.593 | 20.724 | 4.9776 | 0 | 21 | 0 | 9.37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 838 | 2005/02/16 19:02:12.096645 | C | 17.181 | 17.307 | 4.9776 | 0 | 17 | 0 | 8.686 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 839 | 2005/02/16 19:05:15.907737 | C | 20.167 | 20.3 | 4.9776 | 0 | 20 | 0 | 9.272 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 840 | 2005/02/16 19:08:11.586264 | T | 18.096 | 18.229 | 4.97272 | -0.00976 | 18 | 3 | 9.272 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 841 | 2005/02/16 19:11:34.211931 | T | 18.922 | 19.154 | 4.9776 | 0 | 19 | 0 | 8.491 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 842 | 2005/02/16 19:14:38.261684 | T | 17.538 | 17.656 | 4.9776 | 0 | 18 | 0 | 9.467 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 843 | 2005/02/16 19:18:33.312804 | T | 16.917 | 17.156 | 4.9776 | 0 | 17 | 0 | 9.174 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## Appendix D.  Acronyms and Abbreviations

| | |
|---|---|
| A | Ampere |
| BTU | British thermal unit |
| C | charge in Coulombs |
| degC | degree centigrade |
| degF | degree Fahrenheit |
| EU | engineering unit.  Examples:  psi, kPa, micro-strain, g |
| FFT | fast Fourier transform |
| FHT | fast Hartley transform, fast Hilbert transform |
| g | multiples of acceleration of gravity (approximately 32 feet/second/second) |
| GFE | Government furnished equipment |
| GFI | Government furnished information |
| Hz | Hertz |
| ICP | same as IEPE |
| IEPE | integrated electronics piezo-electric (constant current type transducer) |
| IRD | infra-red detector (long range thermal flash detector typically used to detect air bursts) |
| JTFA | joint time-frequency analysis |
| k | kilo (10^ +03) |
| kPa | thousands of Pascals |
| LED | light event detector, detects projectile exit from muzzle, shorter range version of IRD |
| LSB | least significant bits |
| m | milli (0.001) |
| M | Mega (10^ +06) |
| mic | microphone (normally with mic amplifier) |
| MinMeasTime | period of Doppler signal sampling and recording |
| m/s^2 | meters per second per second, acceleration |
| mA | milliamp |
| MPPS | million pulses per second |
| MRSI | multiple round simultaneous impact artillery technique |
| MVR | muzzle velocity radar or Doppler radar velocimeter |
| n | nano (10^ -09) |
| NIST | National Institute of Standards and Technology |
| OEM | original equipment manufacturer |
| OS | operating system |
| p | pico (10^ -12) |
| PE | piezo-electric (charge type transducer) |
| Piezotron | same as IEPE |
| Pmax | peak pressure |
| ppm | parts per million |
| PPS | pulses per second |
| psia | pounds per square inch (absolute) |
| psig | pounds per square inch (gage) |
| s | second |
| S/s | samples per second |
| T0 | time zero, typically the time of day (or leading edge) of a signal pulse that represents initiation of weapon fire |
| t2 | time two, ignition delay period, typically from T0 to weapon pressure reaching 10% of peak pressure |
| t3 | time three, transit period (approx. pulse width) from 10% of peak to muzzle exit |
| t4 | time four, typically the action time of the weapon, calculated by three general methods: (1) start and stop of calibrated universal counter, (2)  (number of sampling cycles between T0 and muzzle exit) x (sampling period),  (3)  (muzzle exit TOD) - (T0) |
| t5 | time five, pressure pulse rise period from 10% to 90% of peak pressure |
| TEDS | transducer electronic data sheet (IEEE 1451 smart type transducer) |
| TOD | time of day |

| | |
|---|---|
| TSMU | time source and measurement unit, ITS model 6115G-TSM |
| TTL | transistor transistor logic, 5 volt driven switching |
| u | micro (10^ -06) |
| uE, u-strain | micro-strain |
| UTC | coordinated universal time (formerly Greenwich Mean Time) |
| uV | micro-volt |
| V | Volt |
| YTC | Yuma Test Center |